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MEMOIRS OF THE GEOLOGICAL SURVEY.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

VOL. I.—TUNGSTEN AND MANGANESE ORES

THIRD EDITION

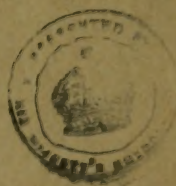
BY

HENRY DEWEY AND H. G. DINES, A.R.S.M., A.M.Inst.C.E.,

WITH CONTRIBUTIONS BY

C. N. BROMEHEAD, B.A., T. EASTWOOD, A.R.C.S.,
G. V. WILSON, B.Sc., AND R. W. POCOCK, B.Sc.

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PREFACE TO THIRD EDITION.

The demand for British tungsten and manganese ores, which was greatly stimulated by the war, has considerably diminished, and many of the mines which were active a few years ago are now closed down. Much work has been done of late years in these deposits, and the information regarding them is now much fuller than when the first edition of this memoir was prepared in 1915. An attempt has accordingly been made to bring the statements and statistics up to date in this edition. Mr. Dines has visited all the principal sources of tungsten in the West of England to collect new information. Messrs. Eastwood and Wilson have revised and supplemented the accounts of the mines in Cumberland and Scotland. During the war Mr. Cantrill and Dr. Sherlock visited the workings for manganese ore in North Wales, and their notes have been made use of by Mr. Dines, who also has made a personal examination of the mines of that district and has contributed the account of them that appears in the following pages. Mr. Dewey has acted as editor of the memoir and has entirely re-written the chapters on tungsten ores of the West of England, a subject of which he has special knowledge. He has incorporated the new information obtained by Mr. Dines and available from other sources and has revised the statistics throughout.

Our thanks are due to owners and managers for the ready assistance they afforded the Survey officers in examining both the mines and the mine plans. Special mention should be made of Mr. Josiah Paull, Capt. Taylor and Mr. T. Bennet for their help in Cornwall and Devon, and to Mr. G. J. Williams, H.M. Inspector of Mines, for valuable information and assistance in connection with the mines of North Wales.

JOHN S. FLETT,
Director.

Geological Survey Office,
28, Jermyn Street,
London, S.W. 1.

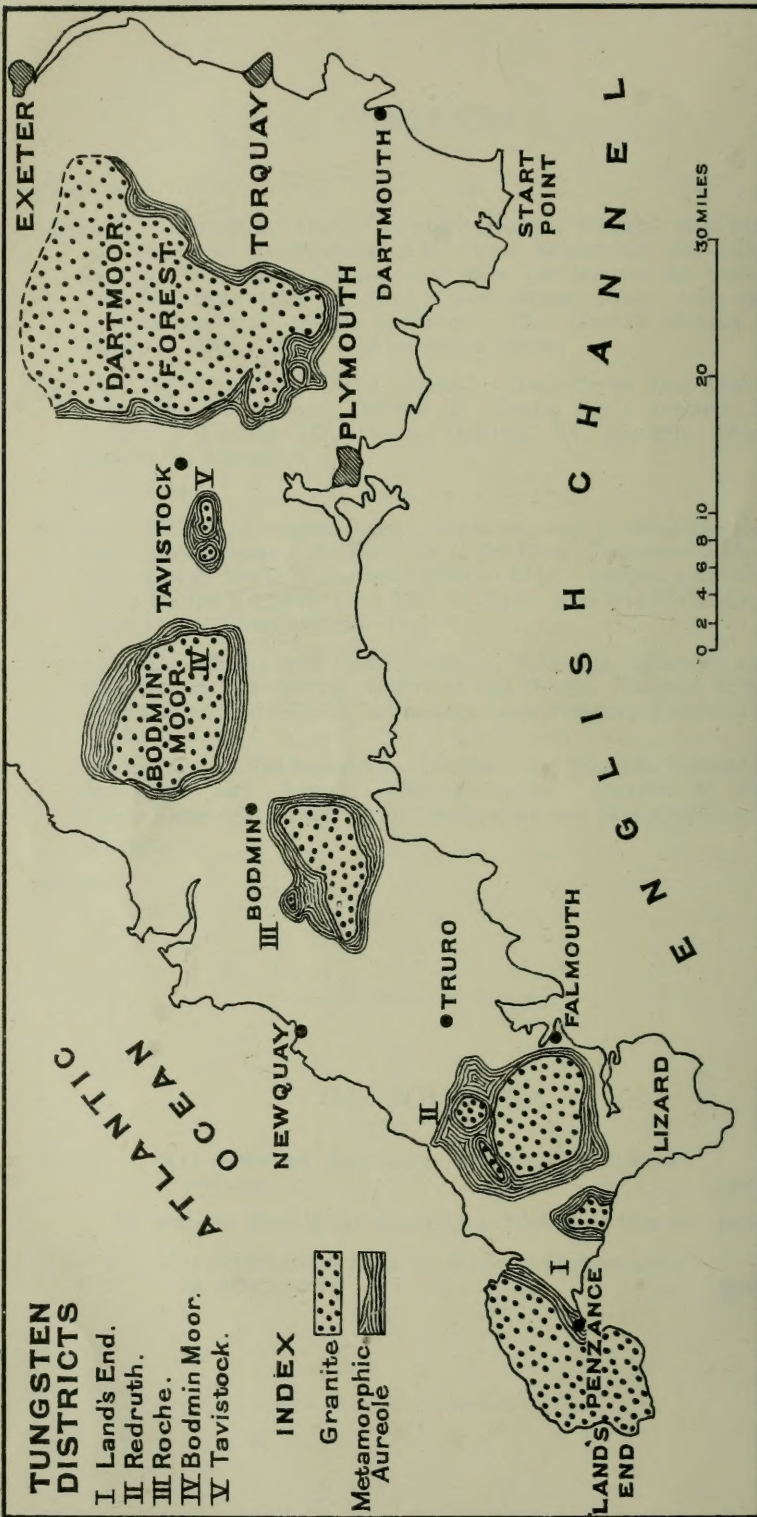
17th January, 1923.

CONTENTS.

	PAGE
PREFACE	iii
CHAPTER I.—TUNGSTEN ORES. INTRODUCTION :—Minerals that contain Tungsten. Distribution of the Ores. Treatment. Estimated Prospective Yield. Output and price per ton in the United Kingdom from 1873 to 1919. Commercial Uses. Rise and present condition of the Industry. The World's Output of Tungsten Ores. Plans of Abandoned Mines	1
CHAPTER II.—TUNGSTEN ORES (contd.). DETAILS OF THE MINES. Cornwall and Devon. District I, Land's End; District II, Redruth; District III, Roche; District IV, Bodmin Moor; District V, Tavistock	11
Cumberland	43
CHAPTER III.—MANGANESE ORES. INTRODUCTION :—Minerals that contain Manganese. Distribution of the Ores. Commercial Uses. Output from North Wales from 1892 to 1913. Output and value in the United Kingdom from 1881 to 1913. The World's Output. Imports into Great Britain	47
CHAPTER IV.—MANGANESE ORES (contd.). GENERAL ACCOUNT AND DETAILS OF THE MINES. Cornwall and Devon. District I, St. Austell Moor; District II, Launceston and Brentor; District III, Exeter	52
Merioneth and Denbighshire. District IV, Harlech, Llanbedr, Barmouth and Arenig. Carnarvonshire. District V, The Lleyl Peninsula. District VI, Derbyshire and Warwickshire	59
Scotland	73
INDEX	76

ILLUSTRATIONS.

	PAGE
PLATE I. MAP SHEWING DISTRICTS IN WHICH WOLFRAM OCCURS	<i>facing</i> 1
II. MAP OF THE WEST CORNWALL WOLFRAM MINES	<i>facing</i> 12
III. MAP SHEWING POSITION OF MANGANIFEROUS BEDS IN MERIONETH	<i>facing</i> 60



MAP SHEWING DISTRICTS IN WHICH WOLFRAM OCCURS.

TUNGSTEN AND MANGANESE ORES.

CHAPTER I.

TUNGSTEN ORES—INTRODUCTION.

MINERALS THAT CONTAIN TUNGSTEN.

Tungsten¹ occurs in nature combined with iron, manganese and calcium in several minerals that are worked commercially. The minerals² are known as ferberite, FeWO_4 , hübnerite, MnWO_4 , wolfram, FeMnWO_4 , and scheelite, CaWO_4 .

Wolfram is the iron and manganese tungstate. It consists of an isomorphous mixture of MnWO_4 and FeWO_4 in variable proportions, the most usual composition being 18·96 per cent. of FeO , 4·67 per cent. of MnO and 76·37 per cent. of WO_3 .

Scheelite is the lime tungstate. It consists of 19·45 per cent. of CaO and 80·55 per cent. of WO_3 .

Wolfram is by far the commonest tungsten-bearing mineral, and occurs in massive, platy or columnar aggregates often of considerable size and black or brownish black in colour. Scheelite is commonly granular or platy, and is grey, yellow, clove-brown or red in colour. To this mineral the Swedes originally applied the term 'tungsten,' meaning 'heavy stone.' Wolfram is a German word, and was apparently applied on account of the mineral causing 'loss of tin in smelting in the same sense that antimony was called "the wolf" by the alchemist, because it devoured the base metals when employed in the refining of gold'.³

DISTRIBUTION OF THE ORES.

Cornwall produces nearly all the tungsten-ores obtained in Great Britain, although a few tons are derived yearly from Devon and Cumberland. The commonest mineral is wolfram, but scheelite occurs in small quantities in Cornwall, Devon and Cumberland and constitutes about three per cent. of the total output of tungsten-ores.

In Cornwall and Devon, wolfram is restricted in its distribution to the neighbourhood of the masses of granite, which are numbered I to V on Plate I. In the Land's End district (I) wolfram has been found only in small quantities but its mode of occurrence is of much interest. It has been found rarely in some mines near Breage, lying north of the Lizard peninsula, and also at St. Michael's Mount.

¹ A full account of the origin of the name and discovery of the metal is given in R. A. Hadfield, 'Alloys of Iron and Tungsten,' *Journ. Iron and Steel Inst.*, No. II, for 1903, pp. 14-118, 1904.

² 'Colorado Ferberite and the Wolframite Series,' by F. L. Hess and W. T. Schaller, *United States Geol. Surv.*, Bull. 583, 1914.

³ Thorpe, 'Dictionary of Applied Chemistry,' vol. v, pp. 562-563, 1913.

The principal district (II) lies between Camborne and Redruth, where the large active mines, South Crofty and East Pool, are situated. The Roche district (III) embraces part of the St. Austell Moor, where wolfram occurs in unimportant quantities in kaolinised granite and also in the killas. A highly productive lode has recently been opened up at Castle-an-Dinas, near the junction of the killas and granite. The Bodmin Moor district (IV) embraces a wide area lying to the north of the moor and some isolated localities near its southern margin. Wolfram was first found in the marshes near Altarnun and the alluvium has long been worked profitably although on a small scale. The source of the alluvial wolfram has been discovered in the pegmatite veins which cut the normal granite, and also in veins where it is associated with cassiterite. At Penhale, on the south of the area, ferberite has been recorded.

The Tavistock district (V) includes the granite bosses of Kit Hill and Hingston Down; the western borders of Dartmoor; and the isolated granite-mass of Hemerdon Ball, near Plymouth.

In Cumberland the tungsten-bearing veins are situated near Carrock Fell.

The minerals that are found with wolfram are similar in all the west of England districts. Wolfram frequently accompanies cassiterite, but more often occurs alone in sheaf-like masses intergrown with quartz and felspar. In some lodes it is intimately mixed with mispickel, chalcopyrite and fluorspar. The association of wolfram with minerals that owe their origin to emanations from the granite, and also its presence in kaolinised granite and in greisen, suggests an origin connected with a late or pneumatolytic stage of the granite intrusions.

At the northern end of Bodmin Moor, although wolfram occurs in lodes with the minerals already mentioned, it is more habitually an original constituent of pegmatite veins, and in some cases apparently of the granite itself. These pegmatite veins are of earlier formation than either the lodes or the greisen. Some of the lode-material at East Pool, however, presents characters which so closely resemble those of the pegmatites that it is difficult to decide whether the lode is normal or a true pegmatite.

Wolfram, in many veins of greisen, is undoubtedly an original constituent; in others, it occurs with quartz in veins cutting through the greisen and therefore of slightly later origin.

In Cumberland the rocks in which the tungsten-ores occur are, in descending order, gabbro, mica-schist and greisen veined with white quartz. Some of the veins carry pockets and occasionally thin streaks of wolfram and scheelite with various other minerals, including galena, pyromorphite, bismuth, bismuth telluride (which contains a little gold), molybdenite, blende, tourmaline, dolomite, mispickel and pyrites. As they pass upwards through the mica-schist into the gabbro the veins are said to deteriorate both in thickness and quality.

In the following pages descriptions are given of the mines that have raised wolfram in sufficient quantity to render its separation from other minerals commercially profitable. There are many other records of the occurrence of the mineral but in such small quantities that detailed descriptions of the mines do not appear necessary. A list of these mines is given on p. 43.

TREATMENT.

Tungsten-ores are generally a by-product at tin mines, and their treatment is in practice bound up with that of tin-ore. As the specific gravity of wolfram and cassiterite is practically the same, the two minerals are concentrated together by gravity, and then separated by their different magnetic properties. A general description of the processes and the machines employed is given below.

The ore lost is almost entirely in the form of slime produced in the batteries; therefore the more waste eliminated before stamping and the coarser the grade of the stamped pulp, provided it can subsequently be treated by the ordinary methods, the better the extraction. The ore is first hand-picked, then sized by means of a 'grizzly': the fragments which cannot pass this are broken in a rock-breaker, more waste being removed by hand until the largest pieces do not exceed $1\frac{1}{2}$ –2 inches. In some cases this process is duplicated, by which means the removal of lumps of granite is carried out more completely.

The ore is now fed to the stamps. Of these the chief types in use are Holman's pneumatic, Californian and Cornish. In the last-named each stamp consists of a head attached to a large vertical stem. They are usually mounted in batteries of five, and are raised by cams set on a revolving drum, which is generally worked by a waterwheel. In the Californian, of which there are several varieties, the stamp is made to revolve, ensuring more even work; the weight may be 1,000 to 1,200 lbs., and the number of blows per minute about 80. The latest type of stamp is the Holman pneumatic. These machines can be run at a higher speed than those worked by gravity. Air is compressed in a cylinder so as to form cushions which decrease the shock and strain on the machine. The standard weight is 1,250 lbs. with a ten-inch drop, and about 130 blows a minute are delivered. In a trial run of 24 hours over 20 tons were crushed by a single stamp at a cost of 1s. 4d. per ton. This Holman stamp is in use at the East Pool Mine.

The size of the screen through which the stamped pulp passes is of importance. Some ten years ago the size usually employed was 20 to 30 mesh. Frequently pierced metal-plates were used in place of woven wire as being more durable. Captain Paull, manager of South Crofty, has advocated coarser crushing,¹ and his example has been generally followed. By employing 14

¹ 'The Advantages of Graduated Crushing.' *Trans. Cornish Institute of Engineers*, vol. i, 1913, pp. 75–94.

mesh he improved the recovery of wolfram by 3·93 per cent., and that of tin to a considerable extent. The following table gives the results of some of his experiments showing the percentage of the pulp and of the total amounts of wolfram and tin which were smaller than 200 size :—

Mesh used.	Pulp — 200.	Wolfram — 200.	Tin — 200.
20	50	76·7	63·6
14	40·4	58·1	—
10	36	51	44·5

That is to say, with 20-mesh screens three-quarters of the total wolfram was in the form of slime, with 10-mesh only about half of it. It is also to be noted that woven wire screens have more than three times the discharging area of pierced plates having the same size of hole.

The pulp now passes through hydraulic classifiers or spitzluten ; these machines are frequently made at the mine to suit the local peculiarities of the ore. The sands are delivered to tables, the slime, after passing a de-waterer or spitzkasten, to vanners or to rag-frames. There are three makes of table in general use, Wilfley, Buss, and James, differing in the manner in which the shock is produced, the supports of the table, and the arrangement of the riffles, which are straight on the Wilfley and oblique on the Buss machines.

The tables usually produce concentrates, middlings and tailings. The concentrates are ready for calcining, the tailings go to waste, the middlings are treated on Frue vanners, where they are sometimes joined by the fines from the classifiers. The heads from the vanners go to the calciner ; the tailings may go to waste or be further treated by a classifier which gives the coarse material to waste and the slimes to frames and buddles, where it would be joined by that from the stamp classifiers, if that is not put over vanners. If the ore treated contains any large quantity of copper pyrites, the mineral may be separated as a third product on the vanners, as its specific gravity is intermediate between that of the gangue and that of the tin-wolfram heads. This method is employed at East Pool and the product sold without further treatment. At South Crofty it is estimated that three-quarters of the tin and wolfram produced comes from 4 Buss tables, only one-quarter from 25 Frue vanners.

Calcination is rendered necessary by the presence of arsenical ores and sulphides. The machine in use is the Brunton calciner. The ore is fed to a revolving floor from a central hopper. As the floor revolves the charge is stirred by groups of fixed flukes, one of which, opposite to the outlet, is set at an angle to the direction of motion and consequently moves the ore continuously from the centre towards the margin where the product is removed. Heat is supplied from a pair of furnaces and the fumes conveyed through flues in which the arsenic driven off from the ore is sublimated. Crude arsenic forms a valuable by-product at all the mines, while at the South Crofty and the Marytavy Mines refined arsenic is prepared in large quantities. Captain Thomas, Manager of the Carn Brea and Tincroft mines, points

out¹ that where the percentage of sulphides in the ore is high the supply of oxygen is too low, while the action of the flukes does not ensure that the whole of the charge is brought in contact with the heated air. At South Crofty, for instance, the wolfram product of the magnetic separator contains 2.2 per cent. of arsenic, and has to be roasted a second time in a tube to remove this impurity.

The after-dressing of the ores varies considerably in detail. At South Crofty three grades are kept separate, of which the coarsest is ready for magnetic separation immediately after calcination. In other mines only two grades are still separate at this stage, the treatment of which is also that of the middle and fine grades at South Crofty. The coarser calcined material passes over tables from which the tailings are pulverised and classified. The process of concentration of the sands is then repeated on tables and vanners. The finest calcined ore goes to vanners and buddles, and the slimes from both are combined and treated on round- and rag-frames.

By the above processes all the metalliferous ores are separated from the gangue and freed from sulphur and arsenic. The separation of the wolfram from the tin cannot be effected in any similar fashion, owing to the practical identity of their specific gravity. In former times a chemical method was necessary, as is still the case where the tungsten-ore is scheelite, or calcium tungstate. Scheelite occurs with tin at Marytavy (see pp. 40-41), but is not now worked. In Cumberland the scheelite is pure, accompanied only by a little blende, which can be removed by treatment on tables, and is not treated chemically at the mines.

The chemical process is expensive. It was first introduced at Drakewalls in 1847 by Oxland, from whom it takes its name. The mixed ore is roasted with sodium carbonate in a reverberatory furnace, by which means sodium tungstate is produced. This salt is soluble and can therefore be washed out and recovered.

In recent times a method of magnetic separation has been utilised. The ore consists principally of magnetic iron oxides, wolfram, and cassiterite, with a small amount of gangue; the first is highly magnetic, the second slightly so, and the tin not at all. The Wetherill magnetic separator consists essentially of four electro-magnets of successively increasing power. The ore is fed on to a travelling belt which passes beneath the poles; between the belt and each magnet is a rubber band travelling at right angles to the belt. The first two magnets are sufficiently strong to attract iron fragments, derived from the wear of the milling machinery, and magnetic oxide; the particles leap up, are caught on the under side of the rubber band, and carried beyond the margin of the belt, where they pass out of the magnetic field and drop off to be collected in a box. The next two magnets are stronger and attract wolfram particles,

¹ 'Losses in the Treatment of Cornish Tin Ores,' *Trans. Cornish Institute of Engineers*, vol. i, 1913. p. 65.

which are discharged into a second box. The tin remains on the travelling belt and drops off into a third receptacle.

The wolfram product is not yet of sufficient purity to be sold. Compound particles consisting of wolfram and quartz cemented by iron-oxide are equally magnetic with pure wolfram; another impurity is tin in the form of fine dust, which is carried along by the stream of particles as they leap towards the magnet. The product of the first magnetic separation is, therefore, treated for some days in a bath of sulphuric acid. This pickling takes place in leaden vats, sometimes steam-heated, the strength of the acid solution being usually about 1 in 8. By this means the iron oxide is dissolved and the grains of wolfram and quartz dissociated. The material is then washed, dried and again passed through the magnetic separator. The final product may be hand-buddled or kieved, ready for sale.

ESTIMATED PROSPECTIVE YIELD.

In estimating the probable future output of wolfram from Cornwall and Devon, two controlling factors must be borne in mind. The first, and most important, is that the mines which produce wolfram are worked primarily for tin-ore, and their future therefore depends in great part upon the maintenance of the price of the best tin. A margin, however, must be allowed for the sale of by-products such as arsenic and wolfram.

The second factor is the increase in the cost of working and draining the mines, which is brought about by increase in depth and rises in wages.

The cost of working per ton of ore at Tincroft Mine varied from 18s. 6d. in 1900 to 28s. 6d. in 1914, the price of tin varying from £62 to £125 per ton during the same period. In 1918 the working costs rose to 42s. 10d. per ton, while the price per ton fluctuated between £269 and £398.

The following table gives the results of working for the year 1918 :—

—	Tons of ore milled.	Tons of material recovered.			
		Black tin.		Wolfram.	
		Tons.	Lbs. per ton of ore milled.	Tons.	Lbs. per tons of ore milled.
East Pool ...	75,401	1,280	38·0	57	1·7
Tincroft ...	54,356	379	15·6	32	1·3
South Crofty ...	67,588	581	19·2	72	2·4
Average ...	65,782	747	24·3	54	1·8

With these results may be compared those obtained at Castle-an-Dinas where 3,500 tons of ore milled yielded 46·5 tons of wolfram or 29·76 lbs. per ton, and at Hemerdon where 5,044

tons of milled ore gave 10 tons of wolfram or 6.2 lbs. per ton. The lode at Castle-an-Dinas is the richest wolfram-bearing lode in Cornwall and Devon.

The recovery of black tin is less than 2 per cent. of the ore milled.

In milling and dressing the ore more than 30 per cent. of it is lost; thus only 2,240 tons were recovered during 1918 from the 197,345 tons of ore milled, instead of 3,200 tons. Captain Thomas, of Tincroft Mine, states¹ that at one of the largest mines the slime-tailings were found, a few years ago, to contain 26 lbs. of tin to the ton. Considerable loss also takes place in the treatment after calcination, and from the imperfect separation of the ores as sold, the wolfram containing 2 to 3 per cent. of cassiterite, and the cassiterite a small quantity of wolfram.

During normal years of work, the annual output of wolfram from Cornwall and Devon may be estimated at 225–295 tons.

The output and price per ton in the United Kingdom from 1873 to 1919 are shown in the following tables:—

Year.	Quantity	Price per ton	Year.	Quantity	Price per ton	Year.	Quantity	Price per ton
	Tons.	£		Tons.	£		Tons.	£
1873	50	10	1889	$\frac{1}{2}$	16	1905	172	66
1874	33	14	1890	104	18	1906	271	74
1875	46	8	1891	138	24	1907	322 $\frac{1}{2}$	127
1876	23	7	1892	125	24	1908	233	81
1877	15	10	1893	22	20	1909	376	85
1878	10	10	1894	—	—	1910	274	107
1879	13	9	1895	—	—	1911	266	98
1880	1	9	1896	43	31	1912	193	87
1881	54	10	1897	125	16	1913	182	97
1882	58	13	1898	326 $\frac{1}{2}$	49	1914	205 $\frac{1}{2}$	96
1883	111	13	1899	94	41	1915	331 $\frac{1}{2}$	125
1884	64	17	1900	9	40	1916	394 $\frac{1}{2}$	126
1885	374	13	1901	21	19	1917	241	164
1886	140	16	1902	9	30	1918	302 $\frac{1}{2}$	162
1887	54	23	1903	272	47	1919	166	116
1888	60	27	1904	161	89			

In 1903 a great demand arose for wolfram in the manufacture of high-speed steels, and the price remained high until the end of the war, when it sank. The tungsten minerals are sold on the basis of their content of WO_3 , the best concentrates containing from 70 to 74 per cent. The average from the Cornish mines ranges from 60 to 70 per cent. The price of the ore per ton (2,240 lbs.) is dependent upon the percentage of WO_3 , a fixed price being paid for each "unit" (per cent.) of WO_3 present. It has varied over a wide range; between 1897 and 1919 it fluctuated between 9s. and 55s. per unit. The price recorded in 1907 was 51s.; in June, 1915, 44s. per unit, or £154 per ton of 70 per cent. WO_3 was offered. Later the price was fixed at a maximum of 55s. per unit. Its present price (1922) with 65 per cent. WO_3 is only 12s. per unit.²

¹ 'Losses in the Treatment of Cornish Tin Ores,' *Trans. Cornish Institute of Engineers*, vol. i, 1913, pp. 56–74.

² *The Mining Mag.*, vol. xxvi, 1922, p. 363.

The output, however, did not follow the price until 1903, when it rose to well over 200 tons a year and remained near or above that amount until the recent fall.

COMMERCIAL USES.

The chief use of tungsten is for hardening iron for the manufacture of high-speed steels, but about 3 per cent. of the world's output is devoted to the manufacture of tungsten-filaments for incandescent electric lamps.

Stellite,¹ an alloy of tungsten, consisting of 55 per cent. cobalt, 33 per cent. chromium and 9 per cent. tungsten, is used for surgical instruments on account of its being unaffected by the organic acids or by antiseptics. It is also employed in the manufacture of saws, knives, chisels and lathe-tools. Amaloy is a similar alloy in which cobalt is replaced by nickel.

Tungsten is being increasingly employed as a substitute for platinum in electrical and X-ray appliances.

The principal salts of tungsten in use are sodium tungstate $\text{Na}_2\text{WO}_4 + 2\text{H}_2\text{O}$, and the so-called sodium meta-tungstate $\text{Na}_2\text{W}_4\text{O}_{13} + 7\text{H}_2\text{O}$. The former is used to saturate materials, with the effect that if they catch fire they smoulder and do not blaze.

The meta-tungstate is employed for the manufacture of tungsten-bronze.

Magenta-bronze is prepared by adding tungsten trioxide to fused potassium, heating the whole in a current of hydrogen and successively digesting with water, hydrochloric acid, water and potash; after this treatment small lustrous violet crystals are obtained, with the composition $\text{K}_2\text{W}_4\text{O}_{12}$.

Saffron-bronze, $\text{Na}_2\text{W}_3\text{O}_9$ is prepared like the potassium salt and forms cubic crystals of a golden hue.

As a *pigment* tungsten is used in place of sodium stannate, especially for dyeing wool and silk.

Metallic tungsten in powder form contains up to 98 per cent. of the metal, and is used in producing tungsten-nickel alloy.

There is also a valuable alloy of tungsten with aluminium known as *partinium*, after Henri Partin, of Paris, which is largely used in automobiles.²

RISE AND PRESENT CONDITION OF THE INDUSTRY.

The industrial properties of tungsten were known in the eighteenth century, for Nicholson's Journal for 1801 states that one "Guyton had melted tungsten, but that it was brittle and probably useless except in alloys or for making 'fixed colours' or fixing vegetable colours."³

The earliest recognised commercial uses of tungsten-ore were for the production of sodium tungstate for fire-proofing, as a mordant, for pigments, and for the manufacture of alloys.

¹ Guillet et Godfroid, 'Quelques Observations sur la Stellite,' *Revue d Métallurgie*, 1918, p. 345.

² See Ohly's 'Analysis, Detection and Commercial Value of the Rare Metals,' Colorado, 1903.

³ Thorpe, 'Dictionary of Applied Chemistry,' vol. v, 1913, p. 562.

In 1847 Oxland took out a patent for the manufacture of sodium tungstate, and another in 1857 for the production of alloys of tungsten with iron and nickel, while Mushet, in 1859, patented another process for the manufacture of tungsten steel, dependent upon his discovery that the self-hardening of steel is due to the presence of tungsten in it.

Taylor and White in 1898 further experimented with ferro-tungsten alloys, but were puzzled by their occasional failures; after a few years, however, they discovered a fact which has revolutionised steel-manufacture, namely that high-speed hardening is due to (super) heating of the alloy. This led to the Taylor-White patent steels.

Up to the year 1903, however, the mineral was regarded as an impurity by the tin-smelters, who heavily penalised the mines for having more than 2 to 3 per cent. of wolfram in their tin concentrates. The specific gravities of tin- and wolfram-ores being practically the same, the only method of separation applicable was the Oxland process, in which a mixture of powdered ore and an excess of sodium carbonate was heated in a reverberatory furnace for about four hours until it became pasty; it was then leached with water, and the solution crystallised and recrystallised until the required standard of purity was reached. Wolfram, however, is slightly magnetic, and is now separated from the tin by an electro-magnet.

THE WORLD'S OUTPUT OF TUNGSTEN ORES.¹

In metric tons.

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	Total.
United Kingdom	278	270	196	185	209	336	400	245	2,119
Burma ...	402	1,353	1,699	1,715	2,364	2,689	3,710	4,553	18,485
Malay States ...	—	188	323	324	436	457	839	1,200 ²	3,767
New South Wales	321	398	231	173	200	84	268	249	1,924
Queensland ³ ...	908	684	831	549	443	662	515	502	5,094
Tasmania ...	68	71	68	69	48	97	108	245	774
New Zealand ...	145	140	137	225	208	196	270	164	1,485
Germany ...	} 60	145	167	150 ²	220 ²	250 ²	300 ²	250 ²	1,542
Austria ...		146	230	245 ²	200 ²	200 ²	200 ²	225 ²	1,476
France ...	30	96	169	150	84	511	651	800 ²	2,614
Spain ...	153	903	1,330	800	967	933	1,418	1,596	8,895
Portugal ...	948	261	205	297	195	439	1,150 ²	1,500 ²	4,297
Japan ...	250	—	—	—	—	—	—	1,200	1,200
China ...	—	—	108	281	30	297	468	634	1,818
Siam ...	—	—	—	—	—	—	—	—	—
United States ...	1,652	1,033	1,207	1,395	898	2,116	4,719	5,000 ²	18,020
Argentina ...	1,912	584	638	539	394	171	700 ²	1,000 ²	5,938
Bolivia ...	207	297	497	564	276	793	920 ²	1,650 ²	5,204
Peru ...	12	48	214	300	196	371	400 ²	1,000 ²	2,541
Total -	-	-	-	-	-	-	-	-	87,193

¹ Rastall & Wilcockson, 'Tungsten Ores.' *Monographs on Mineral Resources*, Imperial Institute, 1920.

² Estimated.

³ Including some mixed bismuth and wolfram.

PLANS OF ABANDONED MINES.

Plans of some of the abandoned wolfram and tin mines referred to in the following pages are preserved at the Department of Mines. The following list is compiled from details published in the official Blue Book: 'List of the Plans of Abandoned Mines deposited in the Home Office,' 1920. Plans with the letter R prefixed to the number, and also those of all mines that had been abandoned for more than ten years on 31 December 1919, are open to inspection:—

(The last column in the following list gives the page of the present volume on which the mine is mentioned.)

Name of Mine.	Parish.	Registered No. of Plan.	Date when received.	Page in text
CORNWALL.				
Arthur	Calstock ...	R. 126	—	34
Balleswidden ...	St. Just ...	34	9.1873	11
"	"	R. 209	—	11
Beam, Great ...	St. Austell	R. 13	1851	23
Callington United, including Holmbush, Red Moor and Kelly Bray.	South Hill and Stoke Climsland	<div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;"> R. 178 R. 260 R. 261 R. 288 4000 4001 </div> <div style="font-size: 3em; vertical-align: middle;">}</div> </div>	1894	31-33
Chacewater or Busy	Chacewater	R. 297	—	20
Gorland	Gwennap	R. 245, 5819	13.5.1912	21
Gunnislake Clitters	Gunnislake	R. 63, 2538	23.3.1891	35
Halvana (Halvinna)	Altarnun	6947	20.10.1919	26
Hawkmoor	Calstock ...	R. 310	—	37
Hingston Down Consols.	Calstock ...	1837	1886	35
Kit Hill	Stoke Climsland.	R. 190 and R. 307	—	32
Maudlin (Magdalen)	Lanlivery	R. 128	—	24
Parkanchy	Gwennap	6946 & 5839	20.10.1919	18
Peavor	Redruth ...	<div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;"> R. 72 3059 </div> <div style="font-size: 3em; vertical-align: middle;">{</div> </div>	1882 1894	19
Poldice	Gwennap	R. 16	—	20
Tincroft	Illogan ...	R. 11, 60	—	12
Treburland	Altarnun	6948	20.10.1919	27
DEVON.				
Bedford United ...	Tavistock	<div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;"> R. 19 2559 </div> <div style="font-size: 3em; vertical-align: middle;">}</div> </div>	—	38
Drakewalls	Calstock ...	4733	—	37
Friendship	Marytavy	4473	—	40

The maps referred to in the following pages are deposited in the Library of the Geological Survey and Museum, Jermyn Street, S.W.1, and may be consulted there.

CHAPTER II.

TUNGSTEN ORES (*continued*).

DETAILS OF THE MINES.

CORNWALL AND DEVON.

DISTRICT I. LAND'S END.

BALLESWIDDEN, ST. JUST IN PENWITH.

(*Idle.*)

The mine lies about a mile west of St. Just and south of the road to Penzance.

Geological and Ordnance maps: One-inch New Series, 351; six-inch Cornwall, 73 N.W.

The country-rock is granite, which is highly mineralised and in part kaolinised. There are three principal lodes, but only the New Lode carries wolfram. It is nearly vertical and contains in addition to wolfram, mispickel, tin- and copper-ore. The adit is sixteen fthms. from the surface and the deepest workings are at 162 fthms. below adit. The mine, which is flooded, has not been worked since 1875, but the dumps have been passed through stamps for tin-ore.

ST. MICHAEL'S MOUNT, MARAZION.

Geological and Ordnance maps: One-inch New Series, 358; six-inch Cornwall, 74 N.E.

"The granite of St. Michael's Mount is somewhat fine-grained, but differs in appearance from either the coarse or the fine variety in the Land's End mass. It is a good deal altered, so that it does not form a good building-stone. . . . The granite foreshore on the east side of the Mount, near the junction with the slate, shows a striking series of parallel vertical joints, up which hot vapours or solutions have travelled, and on each side of these joints the granite has been altered for several inches into 'greisen' or mixture of quartz and white mica, with a certain amount of topaz. These bands of greisen are sometimes so close together that there is scarcely any unaltered rock between; but the maximum alteration is always in close proximity to a vertical fissure. These fissures are really lodes; though here they only contain a little ore. Fine crystals of cassiterite are found, and the other minerals include ores of tungsten, uranium, zinc; apatite and topaz occur also in crystals of considerable size."¹

De la Beche also noted the occurrence of wolfram in long lines in the greisen at this locality.

¹ 'The Geology of the Land's End District' (*Mem. Geol. Surv.*), 1907, p. 48.

LEVANT, ST. JUST IN PENWITH.

(Active.)

The mine is situated near the cliff and about half a mile north of Botallack.

Geological and Ordnance maps : One-inch New Series, 351; six-inch Cornwall, 67 S.W.

The country-rock consists of metamorphosed killas and greenstone overlying granite, but hardly any ore has been found in the latter rock. Some rich lodes have been worked for many fathoms under the sea. The principal ores are those of copper and of tin, but tungsten has been recorded in the form of scheelite. There is also much mispickel. No scheelite has been seen for many years.

NANCEGOLLAN MINE, CROWAN.

(Idle.)

Shafts at a quarter of a mile north-east of Nancegollan station, on the northern side of the road to Porkellis.

Geological and Ordnance maps : One-inch New Series, 352; six-inch Cornwall, 70 S.W.

The mine is situated on the western boundary of the Carnmenellis granite, where that rock emerges from beneath metamorphosed killas. The lode courses E. 40° N., and consists of quartz and capel carrying wolfram, cassiterite and pyrites, with a little fluorspar. A shaft was sunk to a depth of 55 fthms. There is an adit at 20 fthms., below which the mine was kept dry by a small pump. Specimens showing wolfram were obtained in 1915 from the adit.

DISTRICT II. REDRUTH.

TINCROFT, ILLOGAN.

(Idle.)

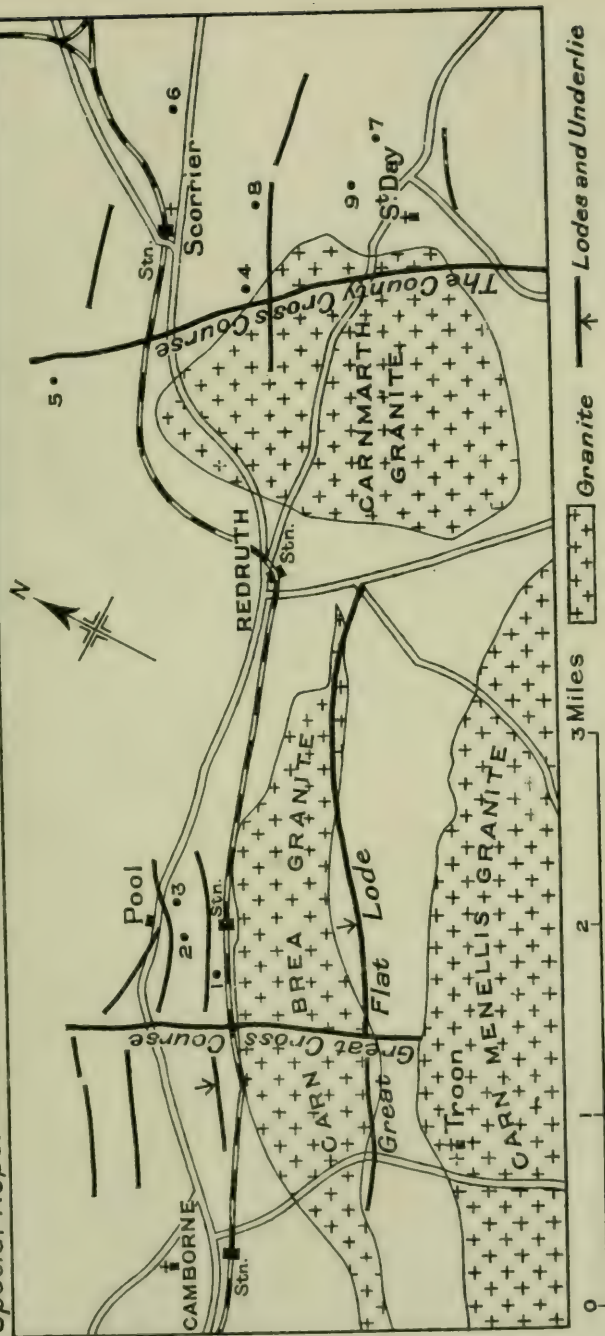
Shafts at Penhellick, near Carn Brea station, and one-third of a mile south of Pool (Plate II).

Geological and Ordnance maps : One-inch New Series, 352; six-inch Cornwall, 63 N.W.

Memoir : 'The Geology of Falmouth, etc.,' pp. 208-210.

Killas forms the country-rock down to a depth varying from 120 fthms. on the eastern to 148 fthms. on the western side of the sett, under which lies the granite. Henwood¹ states that in sinking on Dunkin's Lode the first 26 fthms. were in granite; from 26 fthms. to 84 fthms. in killas; and below 84 fthms. in the main mass of the granite. Adit level lies at 25 fthms. at

¹ 'Geology of Falmouth, etc.,' (*Mem. Geol. Surv.*), 1906, p. 210.



- 1 Tincroft
- 2 South Crofty
- 3 East Pool & Agar

- 4 Parkanchy
- 5 Peavor & North Downs
- 6 Wheal Busy

Granite

3 Miles

2

1

0

Lodes and Underlie

- 7 Poldice
- 8 Killifreth
- 9 North Gorland

MAP OF THE WEST CORNWALL WOLFRAM MINES.

the eastern and at 15 fthms. at the western end of the workings.

The principal lode is the Highburrow Lode, which is a continuation of the Main Lode of Dolcoath. Other lodes are the North Tincroft, Chapple's, Dunkin's, Pryce's and the North Tincroft South Lodes. The lodes last worked for wolfram-ores were the North or Old Tincroft Lode and Pryce's Lode. The Old Tincroft Lode throws off a second lode at 80 fthms. which is known as the Old Tincroft South Lode. The main part continues to a depth varying from 150 fthms. on the east to 175 fthms. on the west, where it merges with Pryce's Lode. The underlie is from 50° to 70° N., while both the South Lode and Pryce's Lode underlie south at 70° to 80° . The lodes all average about 5 ft. in thickness.

The wolfram is usually associated with arsenical pyrites and cassiterite, and locally with fluorspar and copper pyrites. Fluorspar in this mine as in most others was rarely found with cassiterite, but usually with copper-ores, and diminished in quantity at depth. Most of the wolfram-ore came from between the 80- and the 170-fthm. levels, and a small amount with fluorspar at the 190-fthm. level, but it was rarely found with cassiterite. The most productive lodes at Tincroft and Carn Brea were the Druid Lode, where wolfram-ore was found in association with specular iron-ore, arsenate of iron and tin pyrites; and the Barncoose or North Tincroft Lode.

The output of wolfram, up to 1917, averaged about two tons a month. The mine was worked almost continuously from 1815 till 1920, but it is doubtful if it will be reopened. It has yielded nearly 600 tons of wolfram, 25,000 tons of metallic copper and 16,120 tons of black tin.

SOUTH CROFTY (WITH NEW COOK'S KITCHEN), ILLOGAN.

(Active.)

Shafts at Pool, south of the road from Redruth to Camborne, and west of that from Pool to Four Lanes (Plate II).

Geological and Ordnance maps: One-inch New Series. 352; six-inch Cornwall, 63 N.W.

Memoir: 'The Geology of Falmouth, etc.,' pp. 212-213.

The mines in this sett comprise New Cook's Kitchen, West Wheal Crofty and Longclose, South Wheal Crofty, and East Wheal Crofty.

The country-rock consists of altered killas lying to the north of the Carn Brea granite, but the latter rock is encountered at a depth of 120 fthms. to 136 fthms. in New Cook's Kitchen, 140 fthms. to 160 fthms. in South Crofty proper, and at a greater depth further west. Some elvans also occur in the mine. The adit-level is 30 fthms. below the surface, and the levels are named according to their depth in fathoms below the adit.

There are three sections of the mines. Bickford's is the eastern and Robinson's the western part of South Crofty; New

Cook's Kitchen lies towards the south-west of the property. The lodes are numerous, and, as at East Pool, may dip north or south. The former include the North Tincroft Lode and the North Tincroft South Lode. The North Tincroft (or Cook's Kitchen) Lode is called the South Lode in East Pool Mine. Pryce's Lode and the North Lode underlie south, while the Middle Lode is nearly vertical.

The lodes, which are usually tourmalinised, consist mostly of quartz with much chlorite and, here and there, fluorspar; they carry cassiterite, wolfram, copper-ores, mispickel and hæmatite; stannine or bell-metal ore also occurs.

The distribution of the wolfram is irregular; it is most abundant in the middle levels and cannot be depended on below 245 fthms. The most productive lode is not payable much below 245 fthms., at which level the average yield of tin-ore and wolfram together amounts to 23 lbs. per ton: a rise from this level in the western part of the mine showed as much as 40 lbs. per ton.

The North Tincroft Lode in the upper workings underlies at 50° N. down to 130 fthms., but below that it is nearly vertical. At the 205-fthm. level it unites with Pryce's Lode. The North Tincroft South Lode is the South Lode of Cook's Kitchen and the Great Lode of East Pool. It carries wolfram associated with mixed sulphides and arsenides.

The Middle Lode of South Crofty is the Red Lode of East Pool. It is nearly vertical down to about the 240-fthm. level, and then has a southerly underlie. At about 300 fthms. it intersects the North Lode. The lode owes its colour to the presence of much specular iron-ore in association with wolfram. The values vary from 17 lbs. up to 42 lbs. of black tin and wolfram per ton.

Pryce's Lode or the Engine Lode of East Pool underlies south at an average of 65°, and bears E. 15° N. At the 205-fthm. level it joins the South Lode and is from 3 ft. to 5 ft. wide. The lode yielded mainly copper-ore down to the 100-fthm. level, but below this and in the granite mainly tin-ore. The gangue consists of blue capel, peach, quartz, chlorite and fluorspar; but there is comparatively little arsenical pyrites. This is in accordance with the fact that arsenic-ores are rare in lodes with a southerly underlie.

The North Lode underlies south at about 30°, and forms a junction with the Middle Lode below the 260-fthm. level. It varies in width up to 7 ft., and yields for the most part good tin-ore. At the 310-fthm. level it is 2 ft. wide and carries 40 lbs. of black tin to the ton.

In the New Cook's Kitchen Lode wolfram is closely associated with mispickel. A vertical shaft has been sunk about 200 fthms. Down to 175 fthms. the greater part of the ground had been stoped during the old working, but a cross-cut to the north at the 80-fthm. level west encountered a branch of the Main Lode

which was 3 ft. wide and gave 30 lbs. of tin and wolfram to the ton.

Development during the year 1920 took place in the deepest levels at 260 fthms. and 290 fthms. in Robinson's section. Comparatively high assay values have been obtained over portions of the ground, while two new lodes of some promise have been discovered. During this period 69,960 tons of ore were raised and treated, the yield being 589 tons of tin and 38 tons of wolfram concentrates with 645 tons of white arsenic. The yields per ton were 18·8 lbs. of black tin, and 1·22 lbs. of wolfram.

In the Report issued by South Crofty Ltd. for the year 1921 it is stated that since the neighbouring mines, East Pool and Tinroft, had ceased to pump, South Crofty was faced with the task of handling all the water of the three mines. By the installation of a 90-inch Cornish pumping engine and 20-inch Cornish pit work at the New Cook's Kitchen vertical shaft it was submitted that this work could be accomplished. The scheme was placed before the Trades Facilities Committee, who agreed to lend £30,000 at a low rate of interest.

East Crofty Mine was started in 1832 and South Crofty in 1854, mainly for copper-ore. Tin-ore became the main product as the workings increased in depth. Wolfram was first sold in 1869, but during the years 1874 to 1897 only 4 tons were obtained. The following figures from the Home Office statistics up to 1915 and from the Company's Annual Reports since that year give the output since 1907, when wolfram first became an important product at these mines :—

Year.	Tons. Cwt.		Year.	Tons. Cwt.	
1907	51	0	1914	113	4
1908	101	15	1915	97	12
1909	160	9	1916	95	0
1910	131	4	1917	87	0
1911	147	0	1918	87	16
1912	131	0	1919	59	0
1913	117	2			

EAST POOL AND AGAR, ILLOGAN.

(Active.)

Shafts at Pool, midway between Redruth and Camborne (Plate II).

Geological and Ordnance maps : One-inch New Series, 352; six-inch Cornwall, 63 N.W.

Memoir : 'The Geology of Falmouth, etc.,' pp. 219-221.

The country-rock consists of killas, which has been intensely altered by the granite, and is traversed by many lodes and two, or possibly three, elvan dykes. The granite lies 810 feet below the surface at the Engine Shaft, and rises to the surface about a quarter of a mile south-east of it. The important minerals include cassiterite, wolfram, chalcopyrite, mispickel, scheelite

and fluorspar. In some of the lodes there are remarkable intergrowths of wolfram, pyrites, mispickel, quartz and microcline felspar. Parts of the lodes are difficult to distinguish from pegmatite, and all the vertical lodes are granitic.

There are eight lodes, which bear generally E.N.E., and dip either south or north. There is strong evidence that those which dip north were formed previously to those which dip south and have been faulted by them. They are definite clean-cut fissures which have been shifted, along with the elvan dykes and the granite, by the south-dipping lodes, from which they differ in containing an assemblage of sulphide and tungstate ores.

In this mine a downward succession of ores has been proved; copper-ores were predominant from the surface down to 140 fthms.; wolfram from 140 fthms. to 200 fthms., and tin-ore down to 340 fthms., in the south-dipping lodes. In those that dip northward the tin-ores continued down to 450 fthms. The top of the tin zone in the Rogers Lode lies 25–30 fthms. lower than in the Great Lode. The wolfram zone lies approximately at 50 fthms. below the junction of the killas and the granite. This zonal development appears to have arisen as a result of a decrease of temperature rather than by the influence of the country-rock.

The lodes that dip north are, from south to north, as follows :—

The South Lode, and its continuation north of the Engine Lode, the Great Lode. It has an exposure of two miles along the surface. It is the North Entral Lode of Dolcoath, the North Tincroft of Tincroft and the Barncoose Lode of Carn Brea. It has numerous spurs and branches, but none of much importance. The principal are the Copper Lode, the Red Lode, and the Gingerpop Lode. It underlies N. at 20°. At adit-level its width is 1 ft.; below 70 fthms., 1½ to 4 ft.; at 130 fthms., 7 ft. It carries ores of tin, wolfram and arsenic. The South Lode has been faulted up by the New Engine Lode for a distance of 30 to 35 fthms. and so far has not been found north of the New North Lode. Dr. Malcolm Maclaren states that 'it is probable that it will yet be found in the foot-wall of the New North lode during the course of ordinary cross-cutting operations to develop the Rogers lode below the 240 fathom level.'¹ The Great Lode has yielded most of the wolfram raised in this mine. The ore was first encountered at about the 140-fthm. level, and has been worked to below the 300-fthm. level.

The Rogers Lode, with its upper branches, Dobree's, Trembath and the North Lodes, also dips northward. It was first struck at the 160-fthm. level, and later in the granite at the 240-fthm. level. It varies in width but is seldom less than 5½ ft. Its underlie from the 160-fthm. to the 190-fthm. levels is 1½ in 1; from the 190-fthm. to the 212-fthm., 1¾ in 1; and from the 212-fthm. to the 240-fthm., 6 in 1. An account of the development

¹ *The Mining Mag.*, vol. xvi, 1917, p. 248.

of this important lode, to which reference should be made, is given elsewhere.¹ The assay plan shows the following development values of black tin and wolfram :—average over 400 ft. along the 160-fthm. level, 20 lbs. per ton; over 800 ft. along the 190-fthm. level, 78·5 lbs. per ton; over 900 ft. along the 212-fthm. level, 105 lbs. per ton; over 600 ft. along the 240-fthm. level, 36·5 lbs. per ton. Of the last values only 400 ft. were in normal lode material, in which the yield was 100 lbs. per ton. The average width of the lode over all the sections was between 5 and 6 ft. The proportion of wolfram ranged from 1 to 2 lbs. per ton. The ground lying eastward of the East Pool Shaft was found to be less rich than that on the west of it, especially at the lower levels.

The lodes that underlie south are from south to north :—the New South; the Engine Lode Series, comprising the Caunter, the Engine Lode, and in the higher levels Palmer's and Pryce's Lodes; and the New North Lode Series, the principal lodes of which are the Middle Lode and the New North Lode.

The Engine or Main Lode underlies 15° S. to the 36-fthm. level; from the 36-fthm. to the 60-fthm. levels it is vertical, and from the 60-fthm. to the 150-fthm. levels 15° S. It became very poor in depth, but was a strong lode down to 300 fthms. The New North Lode was highly profitable only from the 228-fthm. to the 260-fthm. levels, where the enrichment was probably caused by the intersection of the Great Lode.²

The Middle Lode is one of the vertical lodes. It has been developed at the 200-fthm., the 228-fthm., and the 240-fthm. levels. At 200 fthms. the level has been extended for 35 ft. in ore averaging 45·5 lbs. of black tin and wolfram per ton (2 per cent.) over a width of 4·45 ft. The stope of this drive has assumed considerable dimensions and is furnishing large quantities of ore of higher than average grade. In the 228-fthm. level a winze has been extended for 37 ft. in ore averaging 17·3 lbs. of black tin and wolfram per ton ($\frac{3}{4}$ per cent.) over a width of 4·4 ft. The wolfram is intergrown with microcline felspar. At the 240-fthm. level the north cross-cut has been extended 86 ft.; at 68 ft. the Middle Lode was cut and averaged 13·5 lbs. black tin and wolfram per ton ($\frac{1}{2}$ per cent.) over a width of 4·5 ft.

The gangue of the lodes that underlie south consists of chloritic peach, whereas that of the lodes underlying north is principally quartz.

According to the Report of the Company for the year 1920 the latest development work on the Rogers Lode gave the following results. On the 190-fthm. level the main east drive was continued 248 ft. beyond the elvan in ore averaging 48·5 lbs. black tin and wolfram per ton, over a width of 6 ft. A winze at 520 ft. proved 24 ft. of good lode material, and a rise at 636 ft.

¹ *The Mining Mag.*, vol. xvi, 1917, pp. 249–252, with plans and sections.

² M. Maclaren, *The Mining Mag.*, vol. xvi, 1917, p. 248.

east extended 83 ft. in ore averaging 81 lbs. per ton of the mixed ores, over a width of 6 ft.

On the 212-fthm. level the main west drive was advanced 161 ft., the ore averaging 34.5 lbs. per ton over a width of 6 ft. The main east drive was extended another 129 ft.

On the 240-fthm. level the main west drive was continued 119 ft., the ore over a width of 6 ft. yielding 34 lbs. of black tin and wolfram per ton.

A main north cross-cut was started on the 252-fthm. level from the East Pool Shaft. At 80 ft. the Red Lode, averaging 70 lbs. black tin and wolfram per ton over a width of 5 ft., was intersected. Branwell's Lode was cut at 336 ft. north and averaged over a width of 5 ft. 45 lbs. of black tin per ton; at 430 ft. an 8 ft. lode averaging 37 lbs., and at 537 ft. another averaging 82 lbs. of black tin, were cut through.

The Tolgus tunnel was continued on the 255-fthm. level from the east end of the Agar section. It intersected what is believed to be the Great Lode and for the 11 ft. driven on it the ore averaged 84 lbs. of black tin and wolfram per ton. The full width of the lode is 13 ft. and the ore averages 158 lbs. of black tin and wolfram per ton.

Work has been continuous for 86 years, the first records dating from the year 1835. During that period 42,030 tons of black tin and over 5,700 tons of copper have been raised.

Since 1897 the annual yield of wolfram has been as follows :—

				Tons.					Tons.
1897	...	...	...	101	1908	...	...	57½	
1898	...	...	...	74	1909	...	...	60	
1899	...	...	...	22	1910	...	...	75	
1900	...	...	...	7	1911	...	...	48	
1901	...	...	...	3	1912	...	...	43	
1902	...	...	...	—	1913	...	...	45½	
1903	...	...	...	7	1914	...	...	107½	
1904	...	...	...	13	1915	...	...	127	
1905	...	...	...	49	1916	...	...	100½	
1906	...	...	...	120	1917	...	...	53¾	
1907	...	...	...	73					

PARKANCHY, GWENNAP.

(Idle.)

Shafts situated about five furlongs south of Scorrier station (Plate II).

Geological and Ordnance maps: One-inch New Series, 352; six-inch Cornwall, 63 N.E.

The country-rock consists of tourmalinised biotite-granite, but within 30 yards of the shaft the granite is overlain by knotted micaceous slate belonging to the Mylor Series.

The main lode courses E. 40° N., and is intersected by a small east-and-west lode; the New Lode lies at a short distance to the north, but has not been much worked. Its underlie is northward, but in parts it is vertical. The main lode bears chiefly wolfram;

above the adit it consists of gossany quartz, carrying about 14 lbs. of wolfram to the ton; down to the 20-fthm. level the gossan continues and the values slightly increase. Below that level the quartz becomes solid and is accompanied by fluorspar; the wolfram content averages about 28 lbs. per ton and locally up to 40 lbs. per ton.

The shaft has been sunk to a depth of about 70 fthms., but no stoping has been done below the 36-fthm. level.

In a Report¹ issued in 1917 it was estimated that there were proved 15,000 tons of ore, having a recoverable content of 1 % wolfram concentrate of 65 % WO_3 . The Government advanced a loan of £10,000 for the continuance of operations. In November, 1917, it was 'officially reported that the South lode at the 44 fm. level in the Park-an-chy mine has been driven west for some months past, and that the lode will average 4 % tin and wolfram over a width of 4 ft. Recently, however, the lode has widened to about 10 ft., and the vanning assay shows the lode to average 15 to 17½ %—mostly tin—over 7 ft., the remaining 3 ft. averaging about 2 %.' 'Wolfram ore developed on the main lode, the reserves on which are estimated at 25,000 tons.'² In June, 1918, the mine stopped work.³

PEEVOR AND NORTH DOWNS, REDRUTH.

(Idle.)

Shafts at North Downs, one and a half miles north-north-east of Redruth (Plate II).

Geological and Ordnance maps: One-inch New Series, 352; six-inch Cornwall, 56 S.E.

Memoir: 'The Geology of Falmouth, etc.,' pp. 233–236.

Formerly an important producer of copper-ores.

The country-rock consists of metamorphosed sediments belonging to the Mylor Series, but granite occurs at depth. There are several lodes, common to both mines, coursing about E. 30° N. At Peevor these are intersected by the County cross-course. On the west side of this fault the lodes contain no wolfram, but on the east this mineral accompanies tin-ore. This section of the mine has not been much worked. It is evident that the lodes continue to bear wolfram through the North Downs section, as the dumps from the old workings yield a profitable amount of wolfram.

In 1918 some tin and wolfram were being mined at the 40-fthm. level; it assayed about 1% mixed black tin and wolfram per ton, of which about ½ was wolfram. The output of wolfram from 1912 to 1917 amounted to 5 tons, while in 1918 there was a production of 9 tons of black tin and 3½ cwt. of wolfram.

¹ See *The Mining Mag.*, vol. xvi, 1917, p. 226.

² See *The Mining Mag.*, vol. xvii, 1917, pp. 231–232.

³ See *The Mining Mag.*, vol. xviii, 1918, p. 309.

WHEAL BUSY (THE OLD CHACEWATER MINE), KENWYN.

(Active.)

Shafts four-fifths of a mile north-north-east of St. Day church (Plate II).

Geological and Ordnance maps : One-inch New Series, 352; six-inch Cornwall 57 S.W.

Memoir : 'The Geology of Falmouth, etc.,' p. 223.

The country-rock consists of Lower Palæozoic slates intensely metamorphosed by the granite. This is an ancient mine and was an important producer of copper. It has been worked down to a depth of 220 fthms. There are four important lodes, three underlying north at angles varying from 22° to 47° , and one south at 15° . They all carried ores of copper in the upper levels, with cassiterite at depth. A considerable quantity of arsenical pyrites was raised, and some wolfram.

The North, or Winter's, Lode courses E. 10° N. and is 3 ft. wide. It is said to have assayed 25 lbs. each of black tin and wolfram per ton of ore, some samples yielding as much as 10 % of wolfram. At the foot-wall the Elvan or Felspar Lode occurs. This varies in width from 15 to 40 ft., and bears chiefly arsenical pyrites, but near its hanging-wall there are some patches of cassiterite and wolfram. The lode is stated to have been extensively worked below adit, but not much above that level.

POLDICE, GWENNAP.

(Idle.)

Shafts half a mile north-east of St. Day church (Plate II).

Geological and Ordnance maps : One-inch New Series, 352; six-inch Cornwall, 64 N.W.

Memoir : 'The Geology of Falmouth, etc.,' p. 236.

The country-rock is Lower Palæozoic slate (Mylor Series) greatly metamorphosed by the granite, which lies at 70 fthms. below the surface. It is a very ancient mine and has been worked to a depth of over 250 fthms. below adit. There are many lodes, some underlying northward and others either southward or vertical. The lodes underlying southward have yielded most of the tin-ore and those with a northerly underlie the ores of copper. The tin-ore was partly accompanied by wolfram and during the war some of the dumps were turned over to recover the wolfram.

The output of wolfram for 1917 amounted to $15\frac{1}{2}$ tons, which was sold at an average rate of about £73 per ton.

KILLIFRETH MINE, KENWYN.

(Active.)

Shafts situated about half a mile south-eastwards of Scorrier station (Plate II).

Geological and Ordnance maps: One-inch New Series, 352; six-inch Cornwall, 56 S.E.

The country-rock consists of metamorphosed killas, but granite lies at a depth of about 70 fthms. in the form of a tongue, and again as a tongue in the 20-fthm. level, where it passes into schorl rock. Elvans occur in the 40- and the 50-fthm. levels.¹ There are two lodes, the North Lode and the Middle Lode. A cross-course, containing smaltite, displaces the North Lode about 12 fthms., and also the Middle Lode, which has not been recognised beyond it. The North Lode courses west and underlies north. The Middle Lode courses E. 20° N. and also underlies north. The width of both lodes varies from 1 to 5 ft. The Middle Lode is cut and much disturbed by an elvan. It yields cassiterite and wolfram, with some copper and arsenical pyrites, molybdenite and zinc blende. The ore occurs in bunches yielding up to 112 lbs. per ton of tin and wolfram, but parts of the lode are poor. The lode is filled in places with cassiterite in tourmalinised slate, clear quartz with wolfram, and clear quartz with wolfram and molybdenite in separate layers.² An output of 3,900 tons gave an average recovery of 37 lbs. of black tin and 2½ lbs. of wolfram per ton. Wolfram occurred most commonly between the 30-fthm. and the 50-fthm. levels.

NORTH GORLAND, GWENNAP.

(*Idle.*)

Shafts situated on the south-west side of the road to Scorrier and about 400 yards north of St. Day (Plate II).

Geological and Ordnance maps: One-inch New Series, 352; six-inch Cornwall, 63 N.E.

Memoir: 'The Geology of Falmouth, etc.,' p. 229.

The country-rock consists of granite and the overlying Mylor Series of sediments. The western or Sim's Shaft is entirely in granite, while the eastern or Davy's Shaft enters that rock at adit level, 60 fthms. from the surface.

The main lode bears E. 40° N., and underlies north-westward. The quartz is gossany to the 110-fthm. level. The assay values average 1 % tin and wolfram in the proportion of 5 to 1. The lode at 50 fthms. is about 8 ft. wide, but below that level is divided by a double 'horse'; at the 80-fthm. level the two branches reunite, but no development has been done at this depth.

A second lode, said to be rich in wolfram, and coursing nearly eastward, intersects the main lode, but has not been much worked.

Specimens found on the dumps show wolfram in quartz-felspar-pegmatite and in capel.

The output of wolfram from 1906 to 1911 amounted to 208½ tons. In 1917, 12 cwt. of wolfram were sold.

¹ See M. H. Kitto, *The Mining Mag.*, vol. xxiv, 1921, p. 121.

² *Loc. cit.*

CLIGGA HEAD.

(Idle.)

Cligga Head is situated about a mile from Perranporth.

Geological and Ordnance maps : One-inch New Series, 346; six-inch Cornwall, 47 N.E.

Memoir : 'The Geology of Newquay,' pp. 79-80.

Cligga Head is an isolated boss of granite; it is partly faulted against the surrounding killas, and is much mineralised and riddled with veins of greisen.

The granite cliff, which is 300 feet high, has been searched for tin-ore by the 'old men' by means of numerous levels. The rock is traversed by numerous veins, which vary in width from a mere crack up to six inches or more. The country-rock on either side has been altered to greisen for distances which to some extent depend upon the size of the vein. The minerals that have been found include wolfram, cassiterite, molybdenite, and chalcoppyrite.

'The wolfram is in some of the larger veins very abundant. It forms large masses of a lustrous black appearance, especially where the cleavage faces are exposed . . . it might be thought that it would be worth working this mineral commercially; but here again the sporadic nature of its distribution makes it impossible to be sure of a profit, in spite of the richness of some of the bunches.'¹

GREAT ST. GEORGE AND DROSKYN, PERRANZABULOE.

(Idle.)

Shafts on the cliffs just southwards of Perranporth.

Geological and Ordnance maps : One-inch New Series, 346; six-inch Cornwall, 48 N.W.

The mine was worked for ores of tin and copper, but in 1899 1½ tons of wolfram were raised.

DISTRICT III. ROCHE.

CASTLE-AN-DINAS MINE, ST. COLUMB MAJOR.

(Active.)

Day-levels situated on Castle-an-Dinas hill nearly two miles east-south-east of St. Columb Major.²

Geological and Ordnance maps : One-inch New Series, 347; six-inch Cornwall, 33 S.W.

The country-rock consists of metamorphosed and tourmalinised calcareous sediment, with intrusive tongues of kaolinised granite.

The lode courses N. 15° E. and is nearly vertical. It is remarkably constant in width, averaging about 2½ ft., but varies

¹ 'The Geology of Newquay' (*Mem. Geol. Surv.*), 1906, pp. 79-80.

² See also Davison, E. H., *Geol. Mag.*, 1920, pp. 347-351.

locally from a few inches up to 4 ft. The lode-filling consists almost exclusively of vein-quartz and wolfram. Traces of hæmatite and wad and stains of copper carbonates have been noticed, but cassiterite is so rare that it has never exceeded .3 per cent. of the concentrates. It occurs, however, in the country-rock; assays shewing 1 per cent. Fluorspar and topaz have also been found. The wolfram occurs in masses leaving intervening sections of barren lode; the average recovery has been 30 lbs. per ton. Owing to the clean nature of the lode, ore-dressing is simple and milling-cost low.

The lode has been worked along two levels driven into the hill, the top level being 10 fthms. above the deep one, and about 400 feet shorter. Veins or tongues of thoroughly kaolinized porphyritic granite were met in the deep level at 1,200 feet from the entrance, but a winze sunk to a depth of 90 feet and about 100 feet westwards of the granite was entirely in killas. The top level encountered a small tongue of greisenized granite at about 250 feet from the entrance but almost immediately re-entered the killas. So far the lode has not been traced into the granite at depth and it is not known whether it persists or is shifted at the contact. Although lumps of wolfram have been met with in the tongues of granite, the lode appears to die out. In 1918 there was a development of 1,492 ft. The tonnage milled was 3,500 tons from which $46\frac{1}{2}$ tons of wolfram, valued at £8,890, were produced, or an average recovery of 29.76 lbs. per ton.¹

GREAT BEAM, ST. AUSTELL.

(Idle.)

Shafts and openworks about half a mile west-south-west of Bugle station.

Geological and Ordnance maps: One-inch New Series, 347; six-inch Cornwall, 41 S.E.

Memoir: 'The Geology of Bodmin, etc.,' pp. 159, 165, 168.

The country-rock is kaolinized granite traversed by numerous parallel fissures which do not appear to be faults. Groups of these veins cross the pit from end to end and are of a type characteristic of the district, in which ores occur as stringers.

In addition to the large open workings from which china-clay and ore are obtained, there are several shafts, the deepest of which extends to 92 fthms. below adit; and three main lodes known respectively as the North, the Middle and the South Lode. Both the North Lode and the South Lode contain wolfram. The North Lode is from 4 to 5 ft. wide and consists of decomposed schorlaceous granite carrying cassiterite and wolfram. The South Lode is 5 to 6 ft. wide and consists of a group of veins with tinstone and wolfram in quartz and tourmaline. They course N. 30° E., and underlie N.W.

¹ Cornish Chamber of Mines, 'Year Book for 1918,' 1919, p. 22.

BUNNY, OLD BUNNY OR SHELTON, ST. AUSTELL.

(Idle.)

Large open workings and shaft situated about three miles north of St. Austell, on the west side of the road from Stenalees to Roche.

Geological and Ordnance maps : One-inch New Series, 347 ; six-inch Cornwall, 41 S.E.

Memoir : 'The Geology of Bodmin, etc.,' pp. 138-139.

The country-rock is completely kaolinized granite traversed by numerous parallel cracks wholly or partially filled with vein-materials but shewing no signs of brecciation. In a stope at the 50-fthm. level upwards of twenty-five cracks were counted in a distance of twenty feet. These fissures vary in width from a fraction of an inch up to six inches or even eighteen inches locally. The wider veins consist of coarse drusy quartz forming a comby structure in which are embedded some large crystalline lumps of wolfram and crystals of cassiterite; some tungstic ochre also occurs. The veins course N. 40° E., and underlie 30° N.W. The ore is of a low grade, the average produce of mixed tin and wolfram being about 15 lbs. to the ton. The concentrates averaged 1 per cent. of ore treated, and contained about 40 per cent. of black tin and 20 per cent. of wolfram. Worked originally for tin, the mine was abandoned in 1874, but was reopened in 1901 and worked until 1908. The output for the years 1902 to 1907 inclusive was 82 tons, of which 62 tons were produced in 1904 and 1905. The mine was worked to the 80-fthm. level, the richest ore occurring at the 40-fthm. level.

MAUDLIN, LANLIVERY.

(Idle.)

Shafts near the main road from Bodmin to St. Austell and two miles north-west of Lostwithiel.

Geological and Ordnance maps : One-inch New Series, 347 ; six-inch Cornwall, 34 S.E.

The country-rock consists of killas near the margin of the St. Austell granite. The lode courses E. 23° N. and underlies northward. Scheelite has been found, but not in payable quantities, in association with cassiterite, fluorspar and blende. The mine has not been worked since 1910 and is full of water. Adit-level lies at a depth of 38 fthms. from the shaft-head.

MULBERRY, LANIVET.

(Idle.)

Open workings about a mile and a half north-west of Lanivet church.

Geological and Ordnance maps : One-inch New Series, 347 ; six-inch Cornwall, 33 N.E.

Memoir: 'The Geology of Bodmin, etc.,' pp. 148, 160, 167.

According to Mr. Barrow this mine consists of a large open-work in the killas. The excavation is about 400 yards long by 30 to 50 yards broad and upwards of a hundred feet deep. Minute cracks occur in a belt of ground trending north and south and no trace of a master vein could be seen. The tin-bearing cracks seem practically parallel and trend north-north-east; so that neither the belt nor the cracks correspond in direction with normal tin lodes. The killas is of the banded silt (Meadfoot) type, but it is distinctly more siliceous at the north end of the mine, and in trials and openings still further north thicker bands of rather siliceous rock occur. Much less ore has been met with in these siliceous beds. The banded killas has been completely tourmalinised at the face of the cracks, and all sedimentary material, other than quartz, has been absorbed in the formation of small crystals of schorl, which are arranged criss-cross fashion. A specimen taken nearly two inches from the crack still shews the banding and puckering of the original killas. In the more muddy films about one half is replaced by schorl; but in the more siliceous laminae there is much less of this mineral and the outline of the original elastic quartz-grains is often preserved.

A black film of tin-ore occurs in the crack; the rock on being powdered and vanned yields small crystals or grains which shew the usual strange variation in tint, transparency, and depolarisation so characteristic of these minute grains of tin ore. A fair amount of copper and arsenical pyrites and wolfram are associated with the tin.¹ The cracks vary from mere joints to veins up to 4 or 5 inches in width and rarely more than a foot apart.

The average mineral content appears to be from six to seven pounds of tin oxide to the ton of ore. There is also some wolfram and copper-ore. The ore is free-milling on account of the softness of the killas and the granular character of the cassiterite.

Mulberry is one of the most ancient open-works in Cornwall. It has been described by Sir C. Le Neve Foster² and by Mr. J. H. Collins.³

DISTRICT IV. BODMIN MOOR.

TREVEDDOE, OR WHEEL WHISPER, WARLEGGON.

(Active.)

Shafts situated near Warleggon, about six miles by road from Bodmin.

Geological and Ordnance maps: One-inch New Series, 336; six-inch Cornwall, 27 S.W.

Memoir: 'The Geology of Padstow, etc.,' pp. 103-106.

The country-rock consists of granite and killas, the granite surface sloping to the south-west at nearly 45°. The Main Lode

¹ 'The Geology of Bodmin and St. Austell' (*Mem. Geol. Surv.*), 1909, p. 148.

² *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, p. 122.

³ 'Observations on the West of England Mining Region,' 1912, p. 72.

courses east and west, and ranges from 3 ft. to 6 ft. in thickness. Down to the 32-fthm. level it is vertical; it underlies a little south to the 48-fthm. level and to the north, between the 48-fthm. and the 60-fthm. levels. The country-rock is mineralised near the lode but is not uniformly rich. Assays yield 56 lbs. of black tin from the best ground but there is intervening rock where the yield is as low as 10 lbs. per ton.

Cassiterite was found in the lode down to the 15-fthm. level below adit (adit-level at the shaft is 40 feet), the ore ranging from 56 lbs. to 100 lbs. of black tin per ton. Below this level copper-ores were found and tin-ore fell off slightly. There was a well developed gossan where the green and the blue carbonates, the red oxide of copper and metallic copper were found in good quantities. Wolfram occurs sporadically near the junction of the granite with the killas, but is scarce.

The dressing-plant is operated by water power.

GAZELAND, ST. NEOT.

(Idle.)

Levels on the banks of the St. Neot river about three miles from Doublebois station.

Geological and Ordnance maps: One-inch New Series, 336; six-inch Cornwall, 27 S.E.

The country-rock is metamorphosed killas, in which there are several lodes bearing cassiterite, but only two yield wolfram, which occurs in the form of large lumps. The lodes course east and west.

Two levels, connected by a winze, have been driven, but the lower one is abandoned. The lodes are continuous on both sides of the valley.

The output in 1915 amounted to $1\frac{1}{10}$ tons of wolfram.

HALVANA, ALTARNUN.

(Idle.)

Shaft about a mile east of the main road to Bodmin and twelve miles south-west of Launceston.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 21 N.E.

The country-rock consists of granite veined with pegmatite and aplite, and in places, of mineralised fissures (greisen). There are six narrow lodes all underlying to the south at about 60°. Cassiterite, wolfram, and hæmatite have been found on the dumps. There is also a strip of alluvium on the property which is said to contain tin-stone and wolfram.

During 1916 and 1917 the output of wolfram was 8 tons 7 cwt.

TREBURLAND, ALTARNUN.

(Idle.)

Shafts situated about seven miles south-west of Launceston.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 22 N.W.

Memoir : 'The Geology of Tavistock, etc.,' pp. 80, 82, 113.

The country-rock consists of granite and metamorphosed sediments. There are five lodes, which all underlie south, and a caunter lode. The two lodes which bear wolfram are designated C and D on the mine plan, each being about five feet thick with stringers spreading out into the country-rock. The wolfram occurs only where the lode traverses the granite. The ores associated with it are those of tin and arsenic. Some assays are said to have indicated 60 lbs. per ton, of which 40 lbs. were wolfram and 20 lbs. tin-ore, or 2·68 per cent., a very high percentage.

There are many roughly parallel faults, some of which bear ore-bodies, while others carry quartz and fluorspar, either alone or in addition to the ores.

The adit is 55 feet from the surface of the highest part of the mine. Water does not appear to be heavy. The dumps formerly contained good values of wolfram, but were ransacked during the war.

The output of wolfram in 1915 amounted to 1 ton 7 cwts., and in 1917 to 1 ton 8 cwts.

CANNAFRAME, ALTARNUN.

(Idle.)

Levels beside the main road between Launceston and Bodmin, about a mile north-east of Palmersbridge.

Geological and Ordnance maps : One-inch New Series, 336 and 337; six-inch Cornwall, 21 N.E.

The country-rock is granite which is traversed by pegmatite veins bearing crystalline wolfram. An adit on the east side of the main road cut a lode hading south at 60° and consisting principally of arsenical pyrites with a small quantity of wolfram. On the west side of the road the lode appears to merge into a pegmatite vein carrying arsenical pyrites, cassiterite, chalcopyrite and fluorspar, in addition to wolfram. Still further to the west a sump, fifty feet deep, intersected a small lode hading south at 60° which contained some wolfram but no cassiterite. The wolfram occurred in the form of lumps in which the proportion of ore rose to as much as 60 per cent. The country-rock is cut up by many faults, and lenticles of granite, slickensided deeply on both faces, lie in the veinstuff. It is also traversed by veins of pegmatite in which wolfram forms an original constituent, whereas cassiterite occurs only in the veins of later formation. A narrow, iron-bearing, vein, or plexus of veins, crosses the

main lode. The veins appear to be continuous for 700 to 800 yards in a general east to west direction.

The output of wolfram during 1916 and 1917 amounted to 12 cwts.

WHEAL VINCENT, ALTARNUN.

(Active.)

Shafts beside the main road, about nine miles from Launceston.

Geological and Ordnance maps : One-inch New Series, 337 ; six-inch Cornwall, 21 N.E.

Memoir : 'The Geology of Tavistock, etc.,' pp. 105, 113, 122.

The country-rock is granite, which is altered along fissures into greisen and schorl-rock. There are also veins of pegmatite and of quartz and peach. These veins and the altered granite bear both wolfram and cassiterite, sometimes in minute grains intimately associated, at others in well developed crystals of cassiterite and massive sheaf-like lumps of wolfram. Wolfram is found also as an original mineral in the pegmatite, where it forms large roughly rectangular masses, and apparently also in the granite, but only in small crystals and rarely.

There are five lodes, all underlying south at from 65° to 70° , and known from south to north as the Dorothy, Horseburrow, Streamers, Hendra and Trewint Lodes.

The Horseburrow Lode courses E. 15° N., and dips south at about 70° . In width it ranges from one foot to five feet. Many assays gave an average of 20 lbs. of black tin and 16 lbs. of wolfram per ton. Arsenical pyrites occurs in some quantity. The Streamers Lode is undeveloped and its value unknown. The Hendra Lode dips south at 70° and ranges from two feet to five feet in width. The western part of the lode has been developed by two adits driven into the hill along the lode. The upper level has to some extent been stoped, but the lower level was not opened up, as it met an elvan. Only the eastern part has been developed. Wolfram is visible in the lode, but no ore from the lode has been milled or assayed.

On the Trewint Lode a level has been driven west for a considerable distance, and was worked for tin-ore, but apparently no wolfram was found.

Alluvial.—In addition to the lodes there are about 60 acres of alluvial ground, 40 of which are old stream workings, while the remainder is unworked. The old workings contain about two lbs. of recoverable wolfram per cubic yard, the ore being more or less evenly distributed. The unworked ground carries most of the ore near the bottom of a deposit about ten feet thick which is overlain by three feet of peat. The tests shewed $3\frac{1}{2}$ lbs. of recoverable black tin and wolfram per cubic yard.

The alluvial ground was worked by a steam navvy, with which, however, owing to bad drainage, it was not possible to reach the bottom of the deposit. The bed-rock consists of china clay

with a pitted surface in which good values of ore have been found. It is estimated that there are 750,000 cubic yards of alluvium on the property. An area in which 1,500 cubic yards were worked is reported to have yielded 2·8 lbs. of black tin and wolfram per cubic yard, and in the north valley 1,000 cubic yards of wash returned 3,024 lbs. of black tin and wolfram or 3 lbs. per cubic yard.

The mine was worked originally for tin-ore. It was reopened a few years ago, but has again been abandoned. About 20,000 tons of pay-dirt have been extracted.

BUTTERN HILL, ALTARNUN.

(Idle.)

Day-level on Bodmin Moor, about midway between Camel-ford and Launceston.

Geological and Ordnance maps: One-inch New Series, 336; six-inch Cornwall, 15 S.W.

The country-rock is granite, which is cut by veins of finer grain, consisting of quartz and felspar (aplite) and by others of coarser grain (pegmatite). In addition there are fissures infilled with quartz and metalliferous ores which occasionally cement the brecciated fault-fragments. The walls of these fissures consist of greisen or quartz and white mica, the original felspar of the granite having been converted into these minerals by emanations.

The pegmatite-veins contain large crystalline lumps of wolfram intergrown with orthoclase and quartz, some parts being extremely rich in wolfram. The vein underlies south at 60° and is about a foot thick; in bulk, it contains about four per cent. of wolfram. Most of the lodes in the Redruth district assay about one per cent. of mixed wolfram and tin-ore.

An adit driven into the hill met the lode, and levels were driven both east and west along it. On the east the lode became impoverished in a short distance, but west of the adit the values continued to be good.

Only developmental work has so far been done.

BUTTERN HILL ALLUVIAL WORKS, ALTARNUN.

(Idle.)

The openworks are also known as Nine Stones or Keniton Marsh. They are situated on the Bodmin Moor, about six miles from Otterham station.

Geological and Ordnance maps: One-inch New Series, 336; six-inch Cornwall, 15 S.W.

Nine Stones Marsh covers an area of some 200,000 square yards and lies for the most part on granite. The full thickness of the alluvial deposits has not been ascertained; the sections disclosed by the sluicing operations show an average thickness of

three feet of black earthy peat resting on three to four feet of the 'pay-dirt.' This consists of detritus from the granite and vein-stones, and contains fragments of cassiterite and wolfram. The cassiterite is water-worn into pebbles ranging in size from a small seed up to that of a marble, but the wolfram occurs in less worn splinters and in fine grains. Occasionally lumps of wolfram, three to four inches in length, are found. There is also a large quantity of fine granular ilmenite.¹ The 'pay-dirt' rests on 'shelf,' which consists largely of vein-quartz in pieces about $\frac{1}{8}$ -inch in diameter, with a few fragments of granite. Tourmaline occurs locally and is described by the miners as 'blacks.' This deposit, which is over a yard thick, was found to contain neither wolfram nor tin-stone.

An assay of the wolfram, made for Messrs. King Brothers and communicated by them, gave the following results :

				Per cent.
Tungstic oxide	...	...	...	75.50
Ferrous oxide	...	...	...	14.35
Manganous oxide	...	...	...	8.37
Silica ...	...	...	...	1.55
				<hr/> 99.77 <hr/>

The ores from the districts of Bugle and Illogan contain about 60 per cent. of tungsten.²

Trials made over the whole area are reported to have indicated a yield of $1\frac{1}{4}$ to 12 lbs. of mineral to the yard, while some 'pockets' were much richer. Some ground worked in 1915 is said to have yielded $4\frac{1}{2}$ lbs. of ore per cubic yard. Later work was interrupted by the discovery that much material, hitherto supposed to be wolfram, consisted of ilmenite.¹

HIGHMOOR MINE, ALTARNUN.

(Idle.)

The mine is situated on High Moor. (Lat. $50^{\circ} 36' 10''$. Long. $4^{\circ} 35' 50''$.)

Geological and Ordnance maps : One-inch New Series, 336; six-inch Cornwall, 15 S.W.

The country-rock is porphyritic granite. There are two lodes which course west and underlie at 60° S.

A shaft was sunk to a depth of 45 ft. and a level driven southwards from its base cut a lode containing wolfram. Although payable at this spot the lode was poor elsewhere. Another level, driven northwards, encountered a lode 6 ft. wide which carried good values of cassiterite but was cut out by a fault, and much disturbed.

¹ *The Mining Mag.*, vol. xviii, 1918, p. 199.

² J. H. Collins, 'Observations on the West of England Mining Region,' *Trans. Roy. Geol. Soc. Cornwall*, vol. xiv, 1912, p. 333. Also separately published.

STANNON MARSH, ALTARNUN.

(Idle.)

The marsh lies about three and a half miles from Camelford, the road for the first two miles from the trials being over steep hills.

Geological and Ordnance maps : One-inch New Series, 336 ; six-inch Cornwall, 14 S.E.

Stannon Marsh, now known as Advent Moor, is an almost unworked property. In the north valley the deposit varies in thickness from three to five feet and is overlain by about three feet of peat. A trial-cut, a quarter of a mile long, gave values averaging 4 lbs. of tin-oxide per cubic yard, but only a trace of wolfram was found.

In the south valley, a deposit seventeen feet thick, has been tested, shewing average values of three pounds of wolfram and one pound of cassiterite per cubic yard.

Underlying the alluvium in the south valley there is said to be some china clay of good quality.

OTHER ALLUVIAL PROPOSITIONS ON BODMIN MOOR.

Garrow Downs, and other alluvial tracts, are said to contain wolfram. On Trewortha Marsh wolfram occurs, but in what quantity is not known. The marsh is reached by following a track from North Hill for about four miles. It lies within the one-inch map 337, and the six-inch sheet Cornwall, 22 N.W.

Near Temple (one-inch 336 ; six-inch Cornwall, 27 N.W.), a marsh beside the main road, seven miles from Bodmin, has been prospected, but without satisfactory results.

DISTRICT V. TAVISTOCK.

RED MOOR, SOUTH HILL.

(Idle.)

Shafts situated at Kelly Bray, one mile north of Callington.

Geological and Ordnance maps : One-inch New Series, 337 ; six-inch Cornwall, 29 N.W.

Memoir : 'The Geology of Tavistock, etc.', pp. 103-104.

The country-rock is Upper Devonian slate. There are three lodes which carry tin- and arsenic-ores but wolfram has been recovered from only the North Redmoor Lode and Johnson's Lode. The former courses east, underlies north and is about $4\frac{1}{2}$ ft. wide. Concentrates are said to yield 25 per cent. of white arsenic, 2 per cent. of black tin and some wolfram. The adit is 25 fthms. and the deep adit 80 fthms. below the surface at the shaft. It is a newly discovered lode and has been opened on the 'back' to a depth of 25 fthms. and for a length of 150 fthms.

Johnson's Lode also courses eastward but underlies south. It ranges in thickness from 4 ft. to 6 ft. and carries tin- and arsenic-ores with some wolfram.

A Brunton calciner with 22 chambers and 500 feet of flues and a water tower have been erected.

KIT HILL, STOKE CLIMSLAND.

(Idle.)

Levels and open-cast working situated a little to the east of the summit of Kit Hill.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 29 N.E.

This property was worked by the Duchy of Cornwall. It was given up when the price of tin and wolfram fell shortly after the war.

The country-rock is granite, locally porphyritic, in which there are numerous veins of greisen.

There are ten lodes but only one was worked. This, the No. 1 Lode, strikes E. 10° S. and has been worked down to the water-level at 50 ft. from the surface. Its average width is 4 ft., but in parts it swells out to as much as 15 ft. The yield was 18 lbs. of mixed tin-ore and wolfram per ton.

At the Engine Shaft stopes have been carried to 24 fthms. while development was extended down to 70 fthms. The lode is poor and patchy below 24 fthms., but there remains a considerable amount of mineral in the outcrops and near the surface.

During 1919 and the first nine months of 1920, development amounted to 3,205 ft. From 18,446 tons of ore milled, 55 tons 18 cwt. of black tin, valued at £8,963, and $33\frac{1}{4}$ tons of wolfram, valued at £4,000, were recovered. There were also 20 tons of arsenic valued at £546.

The lodes occurred in the greisen veins. Vein-quartz with cassiterite and wolfram formed the central part of many of these veins while others were barren or contained only vein-quartz.

An aerial ropeway (monocable) extended to the works at Hingston Down, $2\frac{1}{2}$ miles to the east.

The old mine, known as Kit Hill Great Consols, produced 2 tons of wolfram between 1878 and 1897, and a small amount in 1870 and 1872.

EAST KIT HILL, STOKE CLIMSLAND.

(Idle.)

Shafts situated near the Seven Stones, between Kit Hill and Hingston Down.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 29 N.E.

Memoir : 'The Geology of Tavistock, etc.,' pp. 90, 95, 111, 114, 121.

The country-rock is altered Devonian slate. An elvan 30 ft. wide cuts through the killas. The lodes coursing east from Kit Hill to Hingston Down are worked in this mine. Seven were worked, which all carried patches of wolfram of a massive habit mostly free from cassiterite. In the Thirwell section an adit struck four lodes, three of which contain wolfram in massive form but no tin-ore.

The dumps were treated some years ago; the crushed ore shewed about .25 per cent. of black tin. According to the Home Office Statistics this mine in 1898 produced 11 tons of wolfram, valued at £528, and some in 1899.

DIMSON, CALSTOCK.

(Idle.)

Shafts situated about 400 ft. above O.D. at Middle Dimson, half a mile south-west of New Bridge, Gunnislake.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 30 N.W.

The mine is in granite with intrusions of elvan. The lodes course east, but the wolfram occurs also in the north and south cross-courses. The mine is small and was worked by hand in 1913 and 1914; in May, 1915, no mining was being done. There was an output of 11 cwt. of wolfram in 1913.

HOLMBUSH, STOKE CLIMSLAND.

(Idle.)

Shafts situated at about 700 yards north of Kelly Bray.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 29 N.W.

Memoir: 'The Geology of Tavistock, etc.,' p. 98.

The country-rock consists of Devonian slate with an intrusive mass of greenstone, which, however, does not reach the surface.

There are several lodes, from which ores of copper, arsenic, silver-lead, and wolfram have been raised. They have also yielded some iron pyrites, chalybite and fluorspar.

Wolfram was obtained from the dumps during the period 1904-1910. The mixed ores of tin and wolfram were magnetically separated and are said to have yielded 18 lbs. of wolfram per ton.¹

WHEAL BENNY, CALSTOCK.

(Idle.)

Shafts situated on the Cornish bank of the Tamar, and about half a mile south of Luckett.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 29 N.E.

¹ The method of working is described in 'The Geology of Tavistock and Launceston' (*Mem. Geol. Surv.*), 1911, p. 98.

The country-rock is Upper Devonian slate metamorphosed by the Kit Hill granite.

There are three lodes of which only one produces wolfram and that in small quantities. Ores of tin, arsenic and copper are also present.

During a period of four months in 1918 about 600 tons of ore were stamped which yielded $1\frac{1}{2}$ tons of black tin, and 20 tons of concentrates containing 25 per cent. of white arsenic and 3 per cent. of mixed wolfram and black tin. About three tons of arsenic soot were also produced.¹

WHEAL MARTHA, STOKE CLIMSLAND.

(Idle.)

The mine is situated in Luckett village.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 23 S.E.

The country-rock consists of metamorphosed Upper Devonian slate. An adit level driven on the south side of the valley struck three lodes bearing cassiterite and arsenical pyrites with some wolfram and blende. No developmental work has been carried out and the values are unknown.

The dumps from the old workings were turned over, in 1914, in search of wolfram and were afterwards stamped for tin- and arsenic-ores. The concentrates were said to contain a small quantity of wolfram, but it was not separated.

WHEAL ARTHUR, CALSTOCK.

(Idle.)

The mines lie about one mile north of Calstock and include Wheals Arthur and Edward.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 30 N.W.

The mines are worked in Upper Devonian sediments metamorphosed by the granite which outcrops about 900 yds. to the north.

In Wheal Arthur there are eight lodes coursing nearly west and a cross-course through the centre of the sett bearing north. At the junction of the Wheal Arthur with the Wheal Edward sett there are other cross-courses some being 14 ft. wide. Only the Old Lode and the Whimple Lode are known to carry wolfram.

The Old Lode, which is the most important one, has been worked extensively down to the 110-fathm. level. It underlies 40° N., averages 5 ft. in width, and carries ores of copper, tin, arsenic and wolfram. Wolfram has been found only in very

¹ Cornish Chamber of Mines, 'Year Book for 1918,' 1919.

small quantities throughout the lode, but a large patch was struck in the 50-fthm. level, and another in a cross-cut from the Engine shaft at 55 fthms. These patches seem to indicate the occurrence of a caunter lode, but this has not been proved.

The Whimble Lode underlies north and averages $2\frac{1}{2}$ ft. in width. It bears black tin and wolfram averaging about 25 lbs. per ton, but has not been worked below the 50-fthm. level.

GUNNISLAKE CLITTERS AND HINGSTON DOWN, CALSTOCK.

(Idle.)

Shafts situated on Hingston Down, one and a quarter miles west of Gunnislake station. The greater part of the sett is east of a road running north from St. Ann's Chapel to Latchley; the little Miss Joan Shaft is in the plantation on the west of this road. The Clitters Mine is on the Cornish bank of the Tamar due north of Chilsworthy station.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 29 N.E., and Devon, 105 S.W.

Memoir: 'The Geology of Tavistock, etc.,' pp. 97-98.

At Hingston the margin of the highly tourmalinised Devonian slates passes through the works; the eastern part of the mine and the Clitters Mine are in granite.

The lodes of the Hingston Mine have a general bearing E. 12° N. The two principal lodes are known as the Main or Bayly's, and the South or Hitchins' respectively. They underlie north at about 60° . The width of the lodes varies considerably: at 65 fthms. Hitchins' Lode has a width of 20 feet, carries about 3 per cent. of tin-ore and wolfram, and the same amount of arsenic-ore.

Bayly's Lode averages 1.1 per cent. of tin-ore and wolfram and 0.3 per cent. of copper at the 120-fthm., and 1.5 per cent. of tin-ore and wolfram at the 140-fthm. level. At the 172-fthm. level this lode appears to be considerably richer in tin and wolfram and less rich in copper-ore and mispickel.

The workings from the Plantation Shaft are not connected with the main part of the mine, but are on a lode which belongs to a more southern group. The average assay value of this lode is about 1 per cent. of mixed tin-ore and wolfram.

In the Clitters Mine the lodes known as No. 1 and No. 2 are nearly parallel with the Main Lode of Hingston and may be continuous with those at Hawkmoor and Bedford United Mines; they all underlie south. The richest lode appears to be No. 2 which averages $1\frac{1}{2}$ to 2 feet in width, and gives assay values up to 7 per cent. of tin-ore and wolfram, with an average of nearly 3 per cent. A lode a little farther south gave 3 per cent. of the mixed ores over a width of 16 inches, but was not found to be profitable.

The output of wolfram from these mines during the life of the Clitters United and the Hingston and Clitters Companies is given in the Home Office Statistics as follows :—

		Clitters.	Hingston.
		Tons. Cwts.	Tons. Cwts.
1903	...	230 0	—
1904	...	91 0	—
1905	...	62 11	14 15
1906	...	26 15	39 18
1907	...	18 10	48 9
1908	...	4 18	14 11
1909	...	—	28 6

The mines were originally copper mines. Clitters was worked to a depth of 276 fthms. from 1822 to 1827 and 1860 to 1889; Hingston to 172 fthms. from 1850 to 1880; Old Gunnislake was 67 fthms. deep in 1870; it has yielded uranium.

The Clitters United Mines, Ltd., first produced ore in 1903. After reconstruction the Hingston and Clitters Mining Company developed the upper levels at Hingston, drove a cross-cut east from the main works at 110 fthms., deepened Bayly's Shaft by 10 fthms. and drove east and west at 172 fthms. and developed the Plantation Lode, where there are about 5,300 tons of ore proved. These mines were worked by the Duchy of Cornwall from 1916 to 1920.

DOWNGATE CONSOLS.

(Idle.)

Adits and alluvial deposits adjoining the village of Downgate, about one mile north of Callington.

Geological and Ordnance maps : One-inch New Series, 337; six-inch Cornwall, 29 N.W.

The country-rock is killas which has been metamorphosed by the granite.

There are three lodes all coursing east and west. The North Lode and the Middle Lode dip south, and the South Lode north. The Middle Lode has been developed by means of an adit, and a level driven along the lode has proved it to be from three to five feet wide. It contains 20 per cent. of arsenical pyrites, 1 per cent. of black tin and a little wolfram. The adit was extended towards the south and entered the South Lode; wolfram was found but the lode has not been developed.

The alluvium is from ten to fifteen feet thick and is without any overburden except the soil. The ores are scattered evenly throughout the deposit, the recovery of wolfram and black tin being 10 lbs. per ton. Where the alluvium had previously been worked wolfram constitutes 80 per cent. of the remaining ore, whereas in the unworked ground it averages about 25 per cent.

The property was opened up in 1914, but as only wolfram was recovered there is a quantity of black tin left in the dumps. A dressing-plant capable of treating 100 tons a day was installed by the Ministry of Munitions.

DRAKEWALLS, CALSTOCK.

(Active.)

Shafts situated three-quarters of a mile south of Gunnislake, on the Cornish side of the Tamar valley.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 30 N.W.

The country-rock consists of altered killas overlying granite which is entered between the 148- and the 168-fthm. levels. The lodes course E. 5° N.; they are nearly vertical, but the north and south lodes unite at a depth of about 140 fthms. in the Engine Shaft, and at a lesser depth in the western part of the mine. The actual depth of the mine is 190 fthms. at the Engine Shaft, but the depth below the surface is 210 fthms., adit-level being at 20 fthms. below surface. There are large dumps.

The output, between 1852 and 1897 amounted to 5,334 tons of black tin and 2,015 tons of copper-ore.

The Oxland process for the manufacture of tungstate of soda from wolfram was first introduced at this mine in 1854; the tungstate was sold for use in the Manchester textile trade at £14 per ton.

In the Directory of Cornish Mines for 1870, Drakewalls is said to have produced tin, copper and wolfram, the last-named mineral being mentioned at no other mine. The Home Office Statistics records the amount of wolfram produced in 1910 as 13 cwt., valued at £59. Molybdenum-ore has been raised here.

HAWKMOOR, CALSTOCK.

(Idle.)

Shafts situated near the river Tamar, a quarter of a mile north of Gunnislake Bridge.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 30 N.W.

Memoir: 'The Geology of Tavistock, etc.,' p. 97.

The country-rock consists of andalusite-mica-schist overlying greisenized granite, and on the west of the sett faulted by a cross-course against granite at a few fathoms from the surface. There are five lodes now called the North Lode, the Tavistock or Main Lode, and the South Lodes Nos. 1, 2 and 3. These may be the same as those at the Bedford United Mines, the Main Lode and the South No. 1 Lode of Hawkmoor merging into the Tavistock Lode of Bedford United, while the South Lodes No. 1 and 2 unite to form the Marquis Lode. The South Lodes were formerly

known as the Bedford, Bedford No. 1, and the Deal's Kitchen Lodes. They course in a general direction, E. 10° N., but tend to diverge towards the south-west of the property. The North Lode and the Main Lode underlie north at 10° , and the others south. The North Lode is about a foot wide and contains mostly tin- and wolfram-ores. Levels have been driven a short distance into the river bank.

The Main Lode averages in width from 18 in. to 20 in. and contains cassiterite and wolfram with much arsenical pyrites. The gangue consists of vein-quartz and capel with occasional crystals of fluorspar. Near the cross-course there are masses of resplendent green chlorite crystals, forming stellate aggregates up to an inch in diameter. Brecciated andalusite-slate cemented with quartz and fluorspar forms much of the gangue and is especially characteristic near the cross-course, where fragments of greisen are also included. The lode has been worked on to a depth of 80 fthms. at the Eastern Shaft, 43 fthms. at the old Miners', 47 fthms. at Graham's, and 17 fthms. at the Western Shaft. Above the 40-fthm. level the lode has been extensively stoped as far as the Tamar.

A shaft was recently sunk on this lode to a depth of about 10 fthms. and yielded material which, after hand-picking, assayed at 1.68 per cent. wolfram and the same amount of tin.

Bedford No. 1 Lode has not been worked, but a trial-shaft was sunk on it in 1913; some rich specimens of wolfram were lying near it. An adit level has been driven on No. 5 South Lode (or Deal's Kitchen Lode) from the river bank for about 200 fathoms. The lode varies in width from 3 ft. to over 10 ft.; it is not high grade, but there are some rich patches of tin and wolfram. No assay values are available.

Since 1898 the old dumps from the copper-workings have been turned over at least three times and the wolfram picked out by hand. Large quantities of tungsten-ore were sold. Specimens shewing good wolfram values can still be found, and the 'fines' have not been treated.

A little trial work was done in 1912, and $1\frac{1}{2}$ tons of wolfram obtained. In 1916 the output of wolfram amounted to 3 tons 2 cwt.

BEDFORD UNITED, TAVISTOCK.

(Active.)

Shafts situated on the Devon slope of the Tamar valley, half a mile north-east of New Bridge, Gunnislake.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Devon, 105 S.W.

Memoir: 'The Geology of Tavistock, etc.,' p. 107.

The country-rock consists of Upper Devonian sediments.

The lodes are probably the same series as those at Hawkmoor (p. 37) and further west at Clitters (p. 35). They all course about 15° north of east and underlie southward. They carry ores of tin, copper, wolfram and arsenic with fluorspar and quartz. The wolfram occurs in gossany vein-quartz.

No. 1 Lode shows about 1.5 per cent. of mixed black tin and wolfram and 3 per cent. of arsenical pyrites, and has an average width of $1\frac{1}{2}$ ft. The Tavistock Lode has been stoped to a width varying from 2 ft. to 7 ft., while the Deal's Kitchen Lode is about 3 ft. wide.

The mine has been worked to a total depth of 150 fthms. The Marquis Lode, a branch of the No. 1 Lode, was recently reworked down to adit for black tin and wolfram. It had formerly been worked down to the 120-fthm. level for copper-ore only, the black tin and wolfram being left in the lode.

Between 1900 and 1913 the total output of wolfram amounted to 34 tons. During the recent reworking of the mine the output averaged 1 ton of wolfram per month, containing 63.6 per cent. tungstic acid.

FREMENTOR, TAVISTOCK.

(Idle.)

Shafts and day-level at Frementor, on the north bank of the Tamar, about two-thirds of a mile north-west of Gunnislake.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Devon, 105 S.W.

The country-rock consists of greisenized granite faulted at the east end of the sett against killas.

The lode, formerly worked at intervals by open-cast, gives off several small branches, which reunite with it at a depth of a few fathoms. Its general course is nearly west and east, the underlie south, and its average width six feet. It carries ores of tungsten, tin and arsenic, and yields a total of four per cent. of mixed ore. The gangue is quartz with some fluorspar.

At the western shaft there is a remarkable zonal growth of minerals in the lode. Through the greisenized country-rock are scattered large and small sheaves of wolfram crystals. There is next a zone of mixed wolfram and quartz which passes gradually into one of mispickel and chalcopyrite. The centre of the lode consists of quartz and fluorspar with crystals of mispickel. Cassiterite occurs with the wolfram, and, rarely, forms crystals on the surface of the wolfram, but it was not observed accompanying the wolfram next to the greisen.

Development has opened up some good ore-ground, the reserves being regarded as satisfactory. Operations were suspended in 1919 on account of the difficulty of transporting the ore to the Bedford United Mine for treatment, but a light railway connecting the two mines is in course of construction.

WHEAL FRIENDSHIP, MARYTAVY.

(Idle.)

Shafts about half a mile north-north-west of Marytavy church.

Geological and Ordnance maps : One-inch New Series, 338; six-inch Devon, 98 S.W.

Memoir : 'The Geology of Dartmoor,' p. 78.

The country-rock is Culm Measure shale with intrusive masses of greenstone, near the limits of metamorphism effected by the granite.

There are two principal lodes and several small ones and a cross-course.

The scheelite-bearing lode was originally worked for arsenical pyrites. It underlies northwards at 10°. The lode carries considerable quantities of arsenical pyrites, and scheelite occurs in well-formed crystals accompanied by cassiterite and other minerals. Vein-quartz and masses of dolomite are also present.

The average amount of scheelite in the lode is about .5 per cent., but in parts it is as much as 1 per cent.

For many years the dump material was treated for the recovery of tin. The milled product containing tin and scheelite was formerly treated by a modification of the Oxland process, tungstate of soda being manufactured.

In more recent years the scheelite was not separated from the tin-ore, and in consequence the product was sold at a much reduced price.

According to the Home Office Statistics 1 ton of wolfram was produced in 1909 (this record presumably refers to tungstate of soda).

A little scheelite occurs also at the neighbouring mine, Wheal Jewell.

DEVON UNITED, PETERTAVY.

(Idle.)

Shafts beside of the river Tavy about one-third of a mile east, one-sixth of a mile south-east and two-thirds of a mile north-east respectively of Marytavy church.

Geological and Ordnance maps : One-inch New Series, 338; six-inch Devon, 98 S.W.

In the existing sett there are three mines, the North Devon United, the Central Devon United, and the South Devon United. There is also a day-level known as Bennett's adit.

The country-rock consists of greenstone and lava, and slaty killas of Carboniferous age.

There are two lodes in the South mine which underlie south and contain ores of tin and arsenic and some scheelite. They split up and become unworkable at the east end of the property. The gangue is peach with some fluorspar.

In the Central mine there are two lodes, one dipping north and the other south, which die out near their point of intersection. They contain scheelite, arsenical pyrites and cassiterite. The gangue consists of brecciated killas, quartz and peach.

The North mine has been abandoned for nearly a century.

Bennett's Lode dips northwards, courses nearly eastwards and yields arsenical pyrites and a trace of cassiterite but no scheelite. Scheelite was found a few years ago in a cross-cut driven from an old level.

HEMERDON BALL.

(Idle.)

Openworks situated about two and a half miles from Plympton station and seven miles from Plymouth.

Geological and Ordnance maps: One-inch New Series, 349; six-inch Devon, 118 S.E.

The country-rock is coarse-grained granite, tourmalinised and, in part, kaolinized. Numerous veins of greisen traverse it in a general south-westward direction. These veins range in thickness from mere films up to two feet. Many of them are divided into two nearly equal parts by lodes consisting of vein-quartz and wolfram, or of vein-quartz and schorl. The lodes seldom lie in any other position. A wider lode, up to three feet in thickness, is exposed near the plantation; it fades north-west at 47° , and traverses kaolinized and tourmalinised granite. It is much poorer in wolfram than those lying in the greisen veins. No wolfram was observed in the greisen veins, but it occurred commonly in large platy masses lying adjacent to them. On the west the granite is bounded by tourmalinised mudstone and flinty hornfels which carry a little cassiterite, but scarcely a trace of wolfram. The greisen veins terminate abruptly against the kaolinized parts of the granite and appear to be of earlier formation.

In 1917 samples were assayed and said to yield the following results. Those taken from the middle of the productive area (about 18 acres in extent) carried 30 lbs. of wolfram per ton, while the values of others collected along a line trending north-east fell to 12 lbs. a ton, and of those from the south-west of the area to 22 lbs. a ton. The samples from the north-west and the south-east parts of the ground ranged from 3 lbs. to 10 lbs. of wolfram per ton.

According to Mr. E. Terrell¹ the deposit is a true stockwork consisting of a network of small veins, varying in thickness from a fraction of an inch to four feet, and so closely associated that even one foot of intervening granite is unusual. The veins have a general bearing of 25° east of north. The larger ones dip north-west at about 50° from the horizontal.

¹ *The Mining Mag.*, vol. xxii, 1920, pp. 75-87.

To test the productiveness of the ground many prospecting pits were sunk. They measured 6 ft. by 3 ft. and varied in depth from 9 to 12 ft., the greatest depth reached being 44 ft. at the shaft. An excavation called the Long Trench was 70 ft. long, 4 ft. wide and 15 ft. deep.

Mr. Terrell (*op. cit.*) states that the mineral contents of the material excavated averaged 10 lbs. of wolfram and cassiterite per ton. This included the overburden which ranges from 3 ft. to 6 ft. in thickness and contained only 2 to 3 lbs. of ore per ton.

Afterwards systematic exploration of the area was carried out. Pits from 12 ft. to 20 ft. were sunk and the boundaries of the igneous rock defined, the junction with the sediment being vertical. The dissemination of wolfram throughout the prospected area was noteworthy.

Of the material excavated in the igneous ground 109 tons, exclusive of alluvial overburden, were taken for a bulk test. .8 per cent. of wolfram and cassiterite were indicated by chemical assay, and .62 per cent. by vanning assay, the vanned concentrate assaying 68.4 per cent. of wolfram and cassiterite.

The actual final recovery of clean concentrate contained .532 per cent. of these ores, which is equivalent to 11.917 lbs. per ton of 2,240 lbs.

The proportion of WO_3 to SnO_2 was 75.02 to 24.98.

A wet screening test was made on nine tons of ore to ascertain the minus $\frac{1}{8}$ in. material, as it was found that the particles up to this size were sufficiently free of gangue to be recoverable without further crushing. The test resulted as follows: plus $\frac{1}{8}$ in. = 67.08 per cent.; minus $\frac{1}{8}$ in. = 32.92 per cent.

'A proportion of the wolfram in the ore, sufficient to account for just half the difference between the vanning assay result and the total mineral content, was found to be in an extremely fine state, or such other form as to prohibit recovery by any of the ordinary mechanically operated slime-dressing appliances. This is undoubtedly due in the main to disassociation of the crystals, augmented by incipient solvent action, for which the character of the deposit establishes favourable conditions to shallow depths.'

The products were further dressed and passed through a Wetherill-type magnetic separator in which 61.65 per cent. of wolfram was recovered. The wolfram was of a brownish colour, suggestive of incipient decomposition. The non-magnetic residue contained scheelite. All the products were assayed for TiO_2 as ilmenite was known to be a troublesome constituent of some wolfram ores; it occurred in only negligible quantities.

A dressing-plant capable of treating 400 tons of ore a day was installed, but the fall in the price of wolfram on the cessation of war led to the complete stoppage of work. The output in 1918 amounted to 2.8 tons of wolfram; in 1920, to 18.67 tons of wolfram and 4.16 tons of black tin.

List of other mines in which tungsten-minerals have been recorded.

		1 in. Map.	6 in. Map Cornwall.	
Great Wheal Fortune	Breage ...	352	75 N.E.	Wolfram.
Pengelley Croft ...	Breage ...	352	—	Scheelite.
Wheal Herland and Rosewarne.	Gwinear ...	352	69 N.E.	Wolfram.
Dolcoath ...	Camborne	352	63 S.W.	„
Wheal Fanny ...	Illogan ...	352	63 N.W.	„
Harmony & Montague	Redruth ...	352	63 N.E.	„
Pedn-an-Drea ...	„ ...	352	63 N.E.	„
Great Wheal Vor ...	Breage ...	352	75 N.E.	„
Wheal Friendship ...	Gwennap	352	64 N.W.	„
Stenna Gwynn ...	St. Stephen	347	50 N.W.	Wolfram and Scheelite.
Godolphin Bal ...	Breage ...	352	—	Wolfram.
Wheal Prospidnick ...	Sithney ...	352	70 S.W.	„
Goonbarrow ...	St. Austell	347	41 S.E.	Wolfram and Zip- peite.
Balmyrheer ...	Wendron	352	70 N.E.	Wolfram.
Poldory ...	Gwennap	352	64 N.W.	„

OTHER LOCALITIES.

CUMBERLAND.

Cumberland cannot claim to be an important producer of tungsten, but the occurrence is of interest, as Carrock is the only locality in Britain, outside Devon and Cornwall, where tungsten ores are found.

The ores scheelite and wolfram are present in about equal amounts and are chiefly associated with arsenical pyrites and blende, though numerous other minerals are present in small quantities. So far no cassiterite has been met with, though traces of tin have been recognized in some of the assays, and it is possible that deeper workings in the greisen may reveal that mineral.

Carrock Mine, in common with other English tungsten mines, closed down soon after the termination of the war.

Though a considerable amount of work has been done operations have been on too small a scale really to develop the deposits. The present workings are all above valley level, and as the country-rock is not likely to differ greatly from that already met with, it may confidently be expected that large reserves of ore are still available.

Further developments might be more profitably undertaken from lower down the valley and near the junction of Grainsgill Beck and the Caldew. A cross-cut from this direction might

intersect all the lodes at lower levels and possibly prove other lodes as the country-rock would be greisen all the way.

Dressing would be more conveniently carried out at this locality; and, moreover, the Caldew and the whole of Grainsgill Beck would be available for more power than the amount ever likely to be required locally.

CARROCK MINES.

Carrock Syndicate Ltd.; Mr. Anthony Wilson, Thornthwaite Mines, Keswick.

Situated in Grainsgill, a tributary valley of the river Caldew, $4\frac{1}{2}$ miles south of Caldbeck and 3 miles north-west of Mungrisdale.

Maps: One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 S.E.

One of the veins was worked about 60 years ago in Brandy Gill, when a level was driven for about 100 fthms. The vein was lost although short cross-cuts east and west were tried. After that little or no actual mining was done until the period 1901-1905, but most of the work was then only sporadic. After an interval of three years the mine was reopened. For some time night and day shifts were employed and work was prosecuted with vigour, but later was carried on by tributers until the mine was abandoned in 1911. The Carrock Syndicate, Ltd., commenced work about the end of 1913 and made good returns in the latter half of the war, but the mine was closed down soon after the armistice. A few workmen were engaged during 1919 in washing blende.

Several quartz veins accompanied by strings range from Drygill on the north to the valley of the Caldew on the south. About the middle of their course, near Grainsgill and in the neighbouring hillsides, they traverse in an upward direction the greisen of the Skiddaw Granite, mica-schist and the gabbro of Carrock, where many of them carry ores. Of these the chief are wolfram, scheelite, mispickel, pyrite and blende, though numerous other minerals are found including galena, pyromorphite, molybdenite, copper pyrites, tetradymite (bismuth telluride containing a little gold), bismuth, tourmaline, apatite, dolomite, barytes and calcite.

The quartz veins average about 2 ft. in thickness and the ores are usually in small nests and pockets, though occasional strings of wolfram and scheelite occur.

It was once thought that as the veins passed into the overlying gabbro they would deteriorate in thickness and in quality, but in at least one case (Harding's Vein) this supposition has proved to be incorrect.

The most important veins are the Brandy Gill or Emerson's Vein, Harding's Vein, and Smith's Vein, but in addition to these there are several veins and strings some of which are known to carry tungsten though others appear to be barren.

The Brandy Gill Vein was worked recently by levels from a cross-cut near the foot of Brandy Gill. To the south of the cross-cut some of the stoping ground is gossan. To the north the vein consists of white quartz and traverses hard granite except at the far end where it enters soft granite. These workings extend over a length of from 75 to 100 yds. Two older levels were driven above this one. On the south side of Grainsgill, the Brandy Gill Vein was located, but it did not yield much wolfram in a trial drift put in for a distance of about 12 yds.

Harding's Vein, carrying wolfram and marmolite (iron-bearing blende), occurs about 100 yards west of Brandy Gill. A level driven northwards along the vein for 400 ft., begins in mica-schist near the junction with the greisen. At 40 ft. and 90 ft. from the entrance east and west veins carrying lead-ore were encountered, the first being 2 ft. wide and vertical, and the second, 4 ft. wide with a slight hade to the north. The latter vein displaces the tungsten lode 20 ft. to the west. At 220 ft. from the entrance the level enters gabbro—the junction with the mica-schist being rather steeply inclined northwards—and the vein is split locally by a 'horse' about 4 ft. broad and 50 ft. in length.

From the second lead-bearing vein to a short distance beyond the mica schist-gabbro junction the vein has been largely won, but within the gabbro the stopes have been put up only about 40 ft. or about half-way to the surface. No work has been done below the level.

Certain portions of the vein are loughy and contain crystals of quartz up to 2 ft. in length and 6 or 8 inches in diameter. Others loughs near the schist-gabbro junction contain an abundance of fine scales of molybdenite.

On the south side of Grainsgill, on the flanks of Comb Height, Harding's (here known as Combside) Vein averages 2 ft. 3 in. in thickness, though occasionally pinched to 5 in. and assays about 2 per cent. of tungstic oxide. The greater vertical extent of the workings here show that the vein fades westwards; levels have been driven southwards on the vein. No. 4, or Penny Level, begins a few feet above the beck and is now disused. It is 220 ft. in length and much of the ground to No. 3 level, 88 ft. above, is stoped out. The vein at the far end splits into three strings all carrying wolfram and scheelite. No. 3 level has been driven 260 ft. beyond the southern extremity of No. 4. Most of the ground has been won up to No. 2 level (173 ft. above No. 4) with which it is connected by a blindshaft. No. 2 level has been driven for about 210 ft. near the junction of the mica-schist with the underlying greisen. The vein has been partly stoped over a length of 70 yds. up to No. 1 level (242 ft. above No. 4 and about 120 ft. in length). There are small stopes above No. 1, and a little surface work has been done in the mica-schist at the top of the hill.

The other veins and strings have received little attention beyond small trials. Smith's Vein lying about 20 yds. west of Harding's Vein carries tungsten, mainly in the form of fine-grained scheelite, along with arsenopyrite. A string on the west bank of Brandy Gill carries scheelite and arsenopyrite but no wolfram, while east of Brandy Gill two narrow quartz veins show nests of wolfram.

Surface washings anywhere in the vicinity of the lodes show in the pan fair quantities of scheelite, wolfram, and arsenopyrite along with ilmenite derived from the gabbro. Hydraulicing was done for a short time, the concentrates from the flumes being redressed at the mill.

Mining follows normal lines and presents no special difficulties. The lowest levels are above the valley floor and drain the mine. Ore from the levels is trammed to the mill where from the ore bin it passes over a grizzly to a picking-belt and thence to the crusher. Crushed material passes to trommels giving sizes of about $\frac{3}{8}$, $\frac{3}{16}$ and $\frac{3}{32}$ in. Oversizes are returned to the rolls. The first two sizes are jigged, 'chats' being recrushed and treated separately for cleaning up. The $\frac{3}{32}$ in. size and under is thrown on a concave screen, the coarser fragments passing to a Diester sand table and the 'fines' to Wilfley tables, while the slimes are blown through a conical water classifier and then treated on Diester sliming-tables and Isbel vanners.

The concentrate, a mixture of wolfram, scheelite, mispickel and pyrites, is roasted in a furnace with a capacity of $\frac{1}{2}$ ton, and raked by hand. The calcined material is washed and retreated on jigs or tables, and the white arsenic collected from the flues.

Power is derived from two Pelton wheels, using water intercepted midway along Grainsgill, assisted, in dry weather, by a gas engine. A second gas engine drives the compressor and drill sharpener for the three rock drills.

The nearest station is Troutbeck, distant seven miles, with two miles of rough road up the Caldew Valley.

CHAPTER III.

MANGANESE ORES.—INTRODUCTION.

MINERALS THAT CONTAIN MANGANESE.

The minerals that contain manganese in sufficient quantity to be worth working are :

Mineral.	Composition.	Percentage of Manganese.
Polianite	MnO_2	63
Pyrolusite	MnO_2	60–63
Wad	Impure mixture of hydrous manganese oxides.	—
Manganite	$\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$	62
Braunite	From 3 Mn_2O_3 , $\text{MnO} \cdot \text{SiO}_2$ to $4\text{Mn}_2\text{O}_3 \cdot \text{MnO} \cdot \text{SiO}_2$	63
Franklinite	$(\text{FeZnMn}) \text{O} \cdot (\text{FeMn})_2\text{O}_3$	10–19
Dialogite (Rhodochrosite).	$\text{MnO} \cdot \text{CO}_2$	47
Rhodonite	$\text{MnO} \cdot \text{SiO}_2$	42

Psilomelane, 'a hydrous manganese manganate in which part of the manganese is often replaced by barium or potassium, perhaps conforming to H_4MnO_5 (Laspeyres),'¹ is also worked.

Commercial manganese-ores should contain at least 35 per cent. of manganese.

In addition to these minerals there are manganiferous iron-ores which consist of mixtures of manganese and iron oxides. The proportion of iron in such ores is highly variable but usually exceeds 40 per cent.

DISTRIBUTION OF THE ORES.

Nearly all the manganese-ore which is now obtained in Great Britain is raised in the Lley Peninsula in Carnarvonshire, or from mines in Merioneth. Formerly Devon and Cornwall produced manganese-ore, but although the deposits are not exhausted they cannot be worked at a profit at existing prices. The ore for the most part was obtained from the neighbourhood of Launceston in Cornwall and Brentor in Western Devon.

¹ E. S. Dana, 'The System of Mineralogy,' 6th edit., 1903, p. 257. See also L. L. Fermor, *Mem. Geol. Surv. India*, vol. xxxvii, pp. 97–114.

The discovery about the middle of last century of large deposits of manganese-ores in Germany lowered the prices to such an extent that the mines in the west of England were closed down. These mines, with one or two exceptions, have since been worked only intermittently. Prices have been kept low by discoveries in the Russian Caucasus of almost inexhaustible quantities of high-grade ore; as also in the State of Minas Geraes, Brazil. Since 1892 further discoveries of high-grade ore have been made in Bengal, Madras, and the Central Provinces of India. The outputs and imports are given in the tables on pp. 49-51.

Most of the ore from North Wales contains about 32 per cent. of manganese, whereas the ores from India contain from 45 to 55 per cent.; those from Brazil 53 per cent.; and the Russian ore 52 to 56 per cent.

The chief ores in the west of England are pyrolusite and rhodonite, while dialogite predominates in North Wales. In Derbyshire a few hundred tons of wad have been obtained from near Winster.

COMMERCIAL USES.

The chief commercial applications of manganese are :—

1. As an alloy in :

Ferromanganese	} (alloys of iron, manganese and carbon).
Spiegeleisen	
Manganese-steel	
Silicaspiegel (alloy of manganese, iron and silicon).	
Manganese-bronze (alloy of manganese and copper).	
Silver-bronze (alloy of manganese, aluminium, zinc and copper).	

2. As an oxidising agent in :

Glass manufacture, as a decolorizer.
 Electric batteries.
 Drier of varnishes and paints.
 Preparation of chlorine.
 Manufacture of disinfectants (permanganates).

3. As a colouring material in :

Glass, pottery, tiles and bricks.
 Calico-printing and dyeing.
 Paints (brown, green and violet).

4. As a flux in smelting silver- and lead-ores.

Manganese is mainly employed in the manufacture of steel, where it is used in the Bessemer and open-hearth processes as deoxidizer, recarburizer, and neutralizer of sulphur. It is added to the melt in the form of spiegeleisen, an alloy with iron containing from 10 to 40 per cent. but usually about 20 per cent.,

of manganese; or as ferro-manganese with manganese from 40 to 80 per cent.

It is also used in making manganese-steels, to which it imparts great toughness and hardness. About 15 per cent. of manganese is added for this purpose.

Ore used in the manufacture of iron-manganese alloys should contain at least 40 per cent. of manganese and less than 20 per cent. of phosphorus. Silica and other impurities are easily eliminated. For making non-ferrous manganese alloys high-grade ores relatively low in iron are required.

At least 90 per cent. of the World's output of manganese-ore is consumed in the manufacture of iron and steel.

As an oxidizing agent the value of the ore does not depend upon the amount of manganese it contains, but on the amount of available oxygen, *i.e.*, oxygen that can be liberated from it by the action of acids.

The mineral containing the largest amount of MnO_2 is pyrolusite, while psilomelane often contains a considerable quantity of that oxide.

OUTPUT FROM NORTH WALES FROM 1892 TO 1913* (IN TONS).

	Carnarvon-shire.		Merioneth.						
	Rhiw.	Benallt and Nant.	Moelfre.	Cwm Mawr.	Hendre.	Cellfechan.	Llyndy-warchen.	Llyndubach.	Ffridd Tyddyn-du.
1892 ...	—	—	—	—	147	—	50	1,145	—
1893 ...	—	—	—	—	—	—	314	193	—
1894 ...	—	59	—	—	—	—	259	207	—
1895 ...	100	—	—	200	—	—	108	374	—
1896 ...	246	—	—	373	180	—	192	48	20
1897 ...	—	—	—	130	161	—	150	58	—
1898 ...	—	—	—	40	85	—	—	—	71
1899 ...	—	—	—	5	147	28	—	—	148
1900 ...	—	—	—	12	115	277	—	—	600
1901 ...	318	—	—	300	226	150	—	—	210
1902 ...	521	80	—	96	75	80	—	—	232
1903 ...	451	—	—	—	115	120	—	—	99
1904 ...	385	900	—	31	161	90	—	—	—
1905 ...	9,462	4,824	16	—	—	50	—	—	—
1906 ...	2,894	17,300	145	—	—	100	—	—	—
1907 ...	1,083	12,818	182	440	—	41	—	—	175
1908 ...	—	5,937	46	29	—	40	—	—	—
1909 ...	—	2,618	80	—	—	—	—	—	—
1910 ...	—	5,343	124	—	—	—	—	—	—
1911 ...	—	4,809	178	—	—	—	—	—	—
1912 ...	—	3,934	236	—	—	—	—	—	—
1913 ...	—	5,291	102	—	—	—	—	—	—

* From 'Home Office Statistics.'

OUTPUT AND VALUE IN THE UNITED KINGDOM FROM 1881
TO 1913.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Tons.	£		Tons.	£
1881 ...	2,884	6,441	1901 ...	1,646	894
1882 ...	1,548	3,907	1902 ...	1,278	682
1883 ...	1,287	2,976	1903 ...	818	656
1884 ...	909	1,430	1904 ...	8,756	4,370
1885 ...	1,688	2,411	1905 ...	14,474	11,634
1886 ...	12,763	10,893	1906 ...	22,762	22,983
1887 ...	13,777	11,110	1907 ...	16,098	16,516
1888 ...	4,342	1,934	1908 ...	6,308	4,858
1889 ...	8,852	6,478	1909 ...	2,768	2,243
1890 ...	12,444	6,733	1910 ...	5,467	4,673
1891 ...	9,476	6,213	1911 ...	4,987	3,997
1892 ...	6,078	4,434	1912 ...	4,170	3,371
1893 ...	1,336	762	1913 ...	5,393	4,072
1894 ...	1,809	740	1914 ...	3,437	2,931
1895 ...	1,273	681	1915 ...	4,640	4,640
1896 ...	1,080	613	1916 ...	5,140	6,020
1897 ...	599	351	1917 ...	9,942	15,872
1898 ...	231	200	1918 ...	17,456	33,313
1899 ...	415	249	1919 ...	12,078	29,111
1900 ...	1,362	675	1920† ...	12,875	—

* From 'Home Office Statistics.'

† From 'The Mineral Industry of the British Empire and Foreign Countries,' Imperial Mineral Resources Bureau, Statistical Summary, 1921.

THE WORLD'S OUTPUT.

The production in long tons of manganese-ore in the principal producing countries from 1909 to 1917¹ is shown in the following table :—

—	United States.||	Brazil.	Austria-Hungary†	Russia.	United Kingdom.	India.
1909 ...	1,544	236,982	35,096	726,978	2,768	644,660
1910 ...	2,258	249,954	32,445	719,907	5,467	800,907
1911 ...	2,457	171,172	33,769	572,028	4,987	670,290
1912 ...	1,664	152,431	27,514	911,742	4,170	633,080
1913 ...	4,048	120,330	39,612	1,289,370	5,393	815,047
1914 ...	2,635	180,680	*	725,450	3,437	682,898
1915 ...	9,709	284,109	*	50,000†	4,640	450,416
1916 ...	26,966	495,179	*	150,000†	5,140	645,204
1917 ...	122,275†	524,434	*	*	9,942	590,813

¹ From A. H. Curtis, 'Manganese Ores,' *Monographs on Mineral Resources*, Imperial Institute, 1919.

|| Not including manganiferous iron ore.

† Including Bosnia and Herzegovina.

* Not available. † Estimated.

IMPORTS INTO GREAT BRITAIN.*

—			British India.	Brazil.	Russia.	Total from <i>all</i> countries.
			Tons.	Tons.	Tons.	Tons.
1893	...	...	Nil	Nil	59,478	121,773
1894	...	...	Nil	Nil	58,809	127,981
1895	...	...	4,888	6,450	65,474	131,519
1896	...	...	13,686	11,700	55,697	159,982
1897	...	...	23,623	8,210	65,092	156,324
1898	...	...	24,481	8,660	78,170	153,927
1899	...	...	21,005	31,298	140,698	257,608
1900	...	...	36,279	67,563	114,258	265,757
1901	...	...	42,040	34,870	86,166	192,654
1902	...	...	43,174	41,986	112,706	233,333
1903	...	...	58,963	35,971	120,960	231,864
1904	...	...	37,327	52,620	95,840	205,175
1905	...	...	71,660	67,743	87,802	238,700
1906	...	...	121,121	66,557	103,276	338,423
1907	...	...	180,292	72,241	177,664	505,635
1908	...	...	114,900	56,935	106,474	344,170
1909	...	...	109,434	69,899	137,740	330,508
1910	...	...	217,664	80,068	157,331	482,209
1911	...	...	140,633	71,289	137,652	358,915
1912	...	...	168,637	28,111	163,637	387,738
1913	...	...	308,790	18,792	241,894	601,177
1914	...	...	225,086	46,494	177,646	479,435
1915	...	...	348,954	14,515	—	372,724
1916	...	...	421,443	—	—	440,659

* Compiled from 'Home Office Returns and Statistics,' and 'Annual Statement of Trade of the United Kingdom.'

CHAPTER IV.

MANGANESE ORES (*continued*).

GENERAL ACCOUNT AND DETAILS OF THE MINES.

CORNWALL AND DEVON.

The ores of manganese that have been worked in Cornwall and West Devon occur at two principal geological horizons and appear to belong to two distinct periods of formation. The first lies among the calcareous rocks (Meadfoot Beds) of the Lower Devonian formation, where the ore bodies consist of the mixed oxides of iron and manganese. The mines where such ores were raised lie mainly in mid Cornwall between Lostwithiel and St. Columb Major. The ore bodies all course north and south and appear to be true lodes.

The second, or higher, horizon lies near the junction of the Upper Devonian and Lower Carboniferous formations and extends up into the cherts and lavas of the Lower Culm Measures. The ores are to a great extent associated with pillow lavas, cherts and mudstones and may represent deep water deposits similar to those now forming in the Atlantic Ocean. A common mineral is rhodonite. It can frequently be seen to pass laterally into chert stained with manganese compounds and indeed may be the result of reaction of manganeseiferous solutions on the chert. The ores do not appear to form true lodes but rather nodules and lumps in the country-rock. The principal mines lie near Brentor and Launceston.

In east Devon the ores are found where the New Red Sandstone formation overlies the Culm Measures in the country north of Exeter, and in the cherts and mudstones near Doddiscombsleigh to the west of Exeter.

De la Beche pointed out¹ 'the bunches of manganese are not, however, confined to the carbonaceous series being found near Lawinnick, Linkinghorne, and other places; and it is worthy of observation that they are so found under general conditions such as frequent proximity to schistose trappean ash, or compact trappean rocks, which correspond with those under which they are detected in the carbonaceous system.' Again, on p. 286, 'the oxides of manganese frequently occur in bunches, the best bunches being, for the most part, those which are contiguous to the trappean rocks The manganese ores of North Devon are, however, unassociated with trappean rocks, so also are some manganese ores in the St. Austell mining district; and the valuable lode of Upton Pyne, with its continuation on the east and west, is without visible, trappean rocks of importance near it.'

¹ 'Rept. on the Geology of Cornwall, Devon and West Somerset' (*Mem. Geol. Surv.*), 1839, p. 109.

DISTRICT I. ST. AUSTELL MOOR.

WOODLEY AND WEST DOWNS IRON MINES, LANIVET.

(Idle.)

Situated half a mile west-south-west of Lanivet, and about 2 miles from St. Lawrence Halt, G.W.R. branch line from Bodmin to Wadebridge.

Geological and Ordnance maps: One-inch New Series, 347; six-inch Cornwall, 33 S.E.

Memoir: 'The Geology of Bodmin, etc.,' 1909, pp. 158, 163, 164.

The country-rock consists of purple and green, gritty slate, with tourmalinised bands. There are stringers of cassiterite, lumps of hæmatite and small pockets of wad. The lode is said to be 9 feet in width, and contains both red and brown hæmatite, as well as manganese-ore. The ore is said to be remarkably free from sulphur and phosphorus. A shaft a few fthms. deep was sunk, and a level driven to cut the lode. Other lodes in the sett have been found by means of prospecting pits.

The mine was worked in 1859, and from 1871 to 1878 as Lanivet or West Down, during which periods its output of hæmatite and spathose iron-ore amounted to 13,560 tons. Woodley produced 71 tons of hæmatite in 1861.

COLBIGGAN AND RETIRE MINES, ROCHE.

(Idle.)

Situated about a mile east of Withiel Churchtown and about 3 miles from Roche station on the Par and Newquay branch of the G.W.R.

Geological and Ordnance maps: One-inch New Series, 347; six-inch Cornwall, 33 S.E.

Memoir: 'The Geology of Bodmin, etc.,' 1909, pp. 140-141.

The lode has been traced for nearly a mile from south to north in a slightly calcareous slate, which has been in part converted into an intensely hard calc-hornfels containing garnet and axinite.

Between Colbiggan and Wheal James the lode has a bearing of N. 10° W., and according to an old report, varies in width from 5 to 14 feet and occasionally 18 feet. The material consists of red and brown hæmatite, mixed with black oxide of manganese. In the Colbiggan part of the mine a shaft 25 fathoms in depth was sunk, at the bottom of which the lode is from 6 to 8 feet wide. Two other shafts are 7 and 15 fathoms deep respectively. In the Rosewarrick part of the mine the lode has been worked to a depth of 7 fathoms.¹

¹ 'Geology of Bodmin and St. Austell' (*Mem. Geol. Surv.*), 1909, pp. 140-141.

All the ores of manganese and iron are said to have been worked out above the adit-level, which is 40 fthms. below the top of the hill.

In 1874 Colbiggan produced 4,390 tons (mainly hæmatite). Between 1856 and 1870, 23,960 tons of hæmatite were recorded from Retire.

RUTHVOES (OR RUTHERS) AND TRELIVER, ST. COLUMB MAJOR.

(Idle.)

Situated about a mile from St. Columb Road station on the Par and Newquay branch of the G.W.R.

Geological and Ordnance maps : One-inch New Series, 347; six-inch Cornwall, 40 N.E.

Memoir : 'The Geology of Bodmin, etc.,' 1909, pp. 132, 134, 147, 158, 160, 162-165.

The country-rock is slightly calcareous slate altered by contact with the neighbouring granite and tourmalinised. The slate is veined with hæmatite carrying pockets of wad and some ochreous manganese-ore. The lodes course in a general direction of N. 38° W.

The lodes have been quarried from the surface for a depth of about 40 feet. The excavation forms a long trench from the bottom of which levels have been driven along the lodes in the slate.

There is a good deal of hæmatite left, but it is said to be too impure for use in making paint.

The lodes were worked as far back as 1754, the several pits being known as Toldish, Treliver and Gaverigan. Indian Queens yielded 17,847 tons of iron-ore between 1856-1863; Ruthvoes, 1,242 tons in 1872 and 1,022 tons of manganese, while Ruthvoes and Toldish produced 235 tons of umber and ochre in 1901.

RESTORMEL IRON MINE, LANLIVERY.

(Idle.)

Situated about a mile north-north-west of Lostwithiel.

Geological and Ordnance maps : One-inch New Series, 347; six-inch Cornwall, 34 S.E.

Memoir : 'The Geology of Bodmin, etc.,' 1909, pp. 154, 155, 163.

The lodes¹ traverse slightly calcareous slate which in part has been altered by the granite into flinty hornfels.

A series of open pits extends for a distance of about half a mile, and the lode has been seen at various points northwards for some miles. In the great wood at Lanhydrock the lode crops out for a distance of 60 yards with a bearing N. 10° W., and consists of

¹ A horizontal section of the mine showing the extensive stoping is given in the 'Geology of Bodmin and St. Austell' (*Mem. Geol. Surv.*), 1909, p. 155.

quartz and iron-ore. In the principal pits there are two parallel lodes a few fthms. apart with an easterly underlie of 5° to 20° . They contain mainly brown and red hæmatite with patches of pyrolusite and psilomelane, the latter mineral coating the iron-ores.

The first recorded output is for the year 1855, when 20,807 tons of hæmatite were raised; while between 1855 and 1869, 90,810 tons are recorded. In 1882 the ore contained 44 per cent. iron. In 1910 the output was 688 tons of 42 per cent. ore.¹

DISTRICT II. LAUNCESTON AND BRENTOR.

LEWANNICK HILL, LEWANNICK.

(*Idle.*)

Situated about half a mile north-north-west of Lewannick church, and $5\frac{1}{2}$ miles by road from Launceston station, G.W.R.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 16 N.W.

The vein lies in Upper Devonian slate which is overlain by lava. Slate and lava are both stained pink and green in blotches, and streaked with manganese-ore. In the slate these streaks widen into veins and pockets. The ore occurs in the form of black oxide and as silicate of manganese (rhodonite).

TREBURLAND MINE, ALTARNUN.

(*Idle.*)

Situated about 7 miles south-west of Launceston, on the edge of Bodmin Moor.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 22 N.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, pp. 80, 82, 113.

Manganese-ore of poor quality here occurs as wad or black oxide in impersistent seams or pockets; the country-rock being killas altered by contact with the granite.

WEST DOWN END, NEAR TREGEARE, EGLOSKERRY.

(*Idle.*)

Situated about 4 miles west of Launceston.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 16 N.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, pp. 120.

Wad with some rhodonite occurred in veins and lenses among the radiolarian chert of the neighbourhood. In 1879 and 1880 the output amounted to 115 tons of ore.

There is an old shaft and an adit.

¹ 'Home Office Statistics,' p. 245.

LIDCOTT MINE, LANEAST.

(Idle.)

Situated on Laneast Down, near Lidcott Farm, and about 7 miles from Launceston station, G.W.R.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 16 N.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, p. 119.

The mine has been opened in black carbonaceous shale, with beds of grit (Lower Culm Measures). It was worked between 1875 and 1881, when 310 tons of manganese-ore were obtained. The vein was worked out.

BRENTOR AREA.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Devon, 97.

Memoir: 'The Geology of Tavistock, etc.,' 1911, pp. 90, 91, 118-121.

To the north of Brentor there are numerous old manganese mines. The country-rock consists of silicified shales and radiolarian cherts in the Culm Measures. The ore is usually found in the cherty beds, especially in the immediate neighbourhood of igneous rocks, and occurs in irregular veins and stockworks either as the oxides or as the silicate of manganese.

The mines were seldom worked to a greater depth than 10 or 12 fthms., while on Rowden Down open pits about one fathom deep were sufficient to obtain all the ore worth extracting. No work has been done in this district for about 30 years; and it is said that all the accessible ore has been removed.

The names of the mines are Whitstone, East Chillaton, Monkstone, Rowden Down, Westcott, besides several nameless trials.

CHILLATON AND HOGSTOR, MILTON ABBOTT.

(Idle.)

Situated in a wood half a mile south of Chillaton village; one mile and three-quarters from Coryton station by road.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Devon, 97 N.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, pp. 41, 91, 119, 124.

The country-rock consists of cherts and shales belonging to the Culm Measures, with intrusions of greenstone. The ore is mostly pyrolusite, occurring in veins and thin strings which locally swell out to form extensive pockets of rich ground. The larger masses of ore contain small kernels of pink rhodonite.

Work was commenced in 1858, and continued to 1895. In 1902 the mines were reopened, and the following figures shew

the yearly output up to the time when work ceased: 1902, 120 tons; 1903, 15 tons; 1904, 177 tons; 1905, 122 tons; 1906, nil; 1907, 34 tons. The total output for the period 1870 to 1909 amounted to 46,110 tons. From these mines and some smaller workings, 5,769 tons of manganese-ore were raised during the two periods 1858 to 1860 and 1867 to 1868.

SYDENHAM MINE, MARYSTOW.

(*Idle.*)

Situated in Sydenham Wood, on the northern side of the railway, half a mile west of Coryton station.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Devon, 87 S.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, pp. 120, 125.

The mine consists of a shaft and adit driven in the chert beds of the Culm Measures which are traversed by intrusions of greenstone.

The ore is mainly rhodonite, encrusted with oxide of manganese which, in the form of pyrolusite and wad, also fills the joints and cracks in the country-rock.

Ore was first produced at the mine in 1867. In 1870-71 the output was 118 tons.

PENCREBA WOOD, CALLINGTON.

(*Idle.*)

Situated on the north side of the road from Liskeard to Callington, 3 furlongs west of Newbridge.

Geological and Ordnance maps: One-inch New Series, 337; six-inch Cornwall, 29 S.W.

Memoir: 'The Geology of Tavistock, etc.,' 1911, p. 93.

The country-rock here is Upper Devonian slate, much silicified and locally converted to deep-red jasper; there are several intrusions of greenstone in the immediate neighbourhood.

Oxide of manganese is found disseminated through, and lining joints in, the slates. Some massive silicate of manganese (rhodonite) is associated with the pyrolusite. No ore has been raised for many years and the workings are mostly overgrown.

DISTRICT III. EXETER.

LOCALITIES AT HUXHAM, UPTON PYNE, AND NEWTON ST. CYRES.

(*Idle.*)

A large quantity of manganese was obtained in the neighbourhood of Huxham and Upton Pyne, but the ore is said to have been exhausted in 1815. A little trial-work has been done

here and there since that date, mostly about 1875, but all the works have been abandoned for many years.

The localities lie for the most part near the junction of the Culm and the Lower Permian beds. The manganese-ore forms a cement in sandstones, locally swelling out into little pockets. It usually appears under the form of psilomelane and wad, but small nests of manganite are not uncommon.

Owing to the state of the old workings it is impossible to estimate the quantity of ore available.

The chief localities are as follows :—

Huxham, 200 yards south of the church.

Geological and Ordnance maps : One-inch New Series, 325 ; six-inch Devon, 68 S.E.

Memoir : 'The Geology of Exeter,' 1902, p. 110.

An open cut and adit in ruinous condition. Fragments of ore lying about.

Upton Pyne, situated at the eastern end of the village where the road turns northward to Thorverton.

Geological and Ordnance maps : One-inch New Series, 325 ; six-inch Devon, 68 S.W.

Memoir : 'The Geology of Exeter,' 1902, p. 110.

A large open pit now partly filled with rubbish. There are said to be galleries opening from the bottom of the pit, but they are not accessible.

Langford, three-quarters of a mile west of Upton Pyne.

Geological and Ordnance maps : One-inch New Series, 325 ; six-inch Devon, 68 S.W.

Trials for manganese were made here about 25 years ago. They met with little success and the shafts have been filled in.

Newton St. Cyres, about one mile south of the church.

Geological and Ordnance maps : One-inch New Series, 325 ; six-inch Devon, 67 S.E.

Memoir : 'The Geology of Exeter,' 1902, p. 110.

There is an overgrown shaft in a small copse on the east side of the road to Rowherne.

LOCALITIES AT DODDISCOMBSLEIGH AND ASHTON.¹

(Idle.)

Geological and Ordnance maps : One-inch New Series, 325 and 339 ; six-inch Devon, 91 N.E. and S.E.

Memoir : 'The Geology of Exeter,' 1902, p. 110.

¹ In this district much assistance was rendered by Mr. F. G. Collins, who has made a prolonged study of the mines.

At one time manganese-ore was obtained from a number of small mines, but it was neither plentiful nor rich, and no work has been done for about 40 years.

The ore occurs along the bedding in the Lower Culm Measures, for the most part where the slate is silicified or in beds of hard chert, and in the neighbourhood of igneous rocks. Rich bunches are sometimes found, but these have, so far as is known, been worked out, and no ore has been raised since 1875.

Only oxides of manganese have been recorded, in the form of manganite, or grey manganese, pyrolusite and wad.

SCANNICLIFT COPSE, DODDISCOMBSLEIGH.

(Idle.)

Situated about one mile west of Doddiscombsleigh.

Geological and Ordnance maps: One-inch New Series, 325; six-inch Devon, 91 N.E.

Memoir: 'The Geology of Exeter,' 1902, p. 111.

There is an old adit, much overgrown. The Culm Measures are silicified, and include beds of chert and red jasper. A bed of highly vesicular spilite also occurs. The manganese-ore is disseminated through both the sedimentary and the igneous rocks.

HAREHILL PLANTATION, DODDISCOMBSLEIGH.

Situated 350 yards south of Doddiscombsleigh church.

Geological and Ordnance maps: One-inch New Series, 325; six-inch Devon, 91 N.E.

An adit and a shallow shaft have been driven for manganese-ore on the northern margin of the copse; there is also an open cut in the copse, now completely overgrown. The ore consists of wad and pyrolusite occurring in hard mudstones which pass upward into chert.

Some other localities where a few tons of manganese-ore have been raised are mentioned in the Geological Survey Memoirs on Sheets 325 and 339.

MERIONETH AND DENBIGHSHIRE.

DISTRICT IV. HARLECH, LLANBEDR, BARMOUTH AND ARENIG.

The manganese-ore of West Merioneth occurs in bedded form and consists of mixed carbonate (dialogite) and silicate (rhodonite). There may be one or more beds interstratified in the Harlech Grit Series of the Lower Cambrian rocks. In 1893 J. G. Goodchild,¹ as a result of a brief survey of these ore-deposits,

¹ MS. six-inch Geological Maps, Merioneth, 26 N.W., S.E.; 31 S.E.; 32 N.E.; and 36 N.W., deposited in the Library of the Geological Survey.

concluded that there are two beds of ore. He grouped the country rocks in the following order :

1. Upper Mudstones (Lingula Flags and Menevian); *Upper Manganese Bed* at base.
2. Upper or Moelfre Grits.
3. Lower Mudstones : *Lower Manganese Bed* near base.
4. Lower Grits.

According to his classification at least 850 ft. of rocks must separate the two beds of ore. Prof. Chas. Lapworth and Dr. T. Stacey Wilson, however, recognised only one bed¹, which seems to be in the position of Goodchild's Lower Bed.

The bed varies in thickness from ten to twenty inches, and is coated near the surface, and on the joints and cracks, with black oxide of manganese, a decomposition product, which contains from 20 to 32 per cent. of metallic manganese. It is everywhere underlain by a bed of grit containing numerous cubes of iron pyrites. The richest ore, which is essentially pyrolusite, consists of the weathered crust. This was formerly dug, and the carbonate and silicate rejected as useless; but the discovery of the value of the mixed carbonate and silicate in glass-making led to the reworking of many pits that had been exhausted of their black oxide. An exceptional demand for manganese was brought about by the Russo-Japanese war and the North Wales mines produced over 22,000 tons of ore.

During the late war the mines were worked on a scale that is unlikely to be equalled again, although there appear to be large reserves of ore below the existing shallow workings.

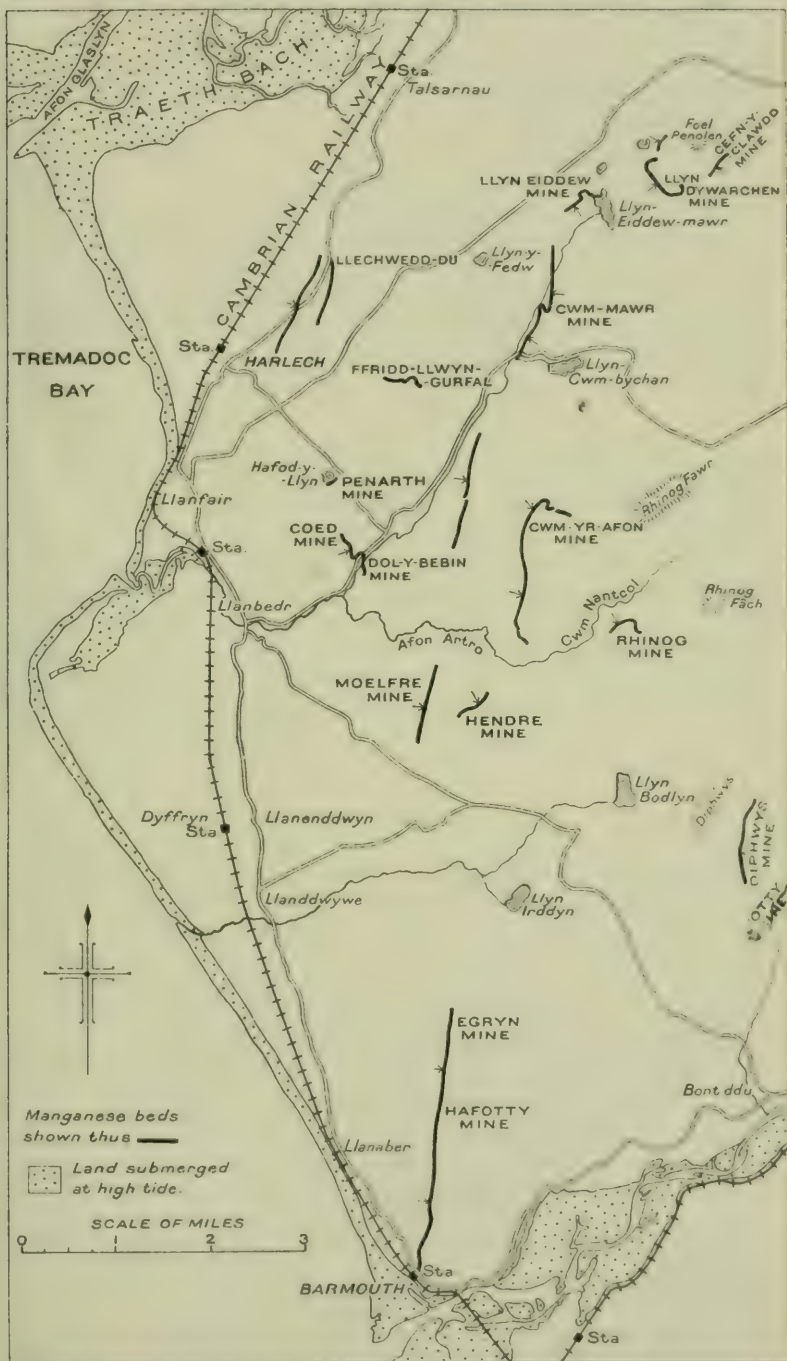
The ore is won by open works or day-levels on or near the more clearly defined and easily traced outcrops. In the Harlech and Llanbedr district (Plate III) the outcrops have been worked or tested for short distances, seldom over a mile in length, separated by long intervals in which the bed is hidden under glacial drift or scree, or through lack of natural exposures has not been detected.

The distribution of the known ore-occurrences is shewn on Plate III. For purposes of description there are assumed to be two beds as suggested by Goodchild, the lower having been wrought in the western district and the higher in the eastern and north-eastern areas.

The Lower Manganese Bed.

Two miles north-east of Harlech a short length of outcrop has been located at Llechwedd-du, and there are some old levels farther south towards Capel-Engedi (two-thirds of a mile south-east of Harlech). A bed of ore crops out at Hafod-y-llyn, 1½ miles east of Llanfair, which appears to be at the same horizon

¹ Cited in A. R. Andrew, 'The Geology of the Dolgelley Gold-belt, North Wales,' *Geol. Mag.*, 1910, p. 161.



MAP SHOWING POSITION OF MANGANIFEROUS BEDS IN MERIONETH.

as that worked in the Artro valley. Here and in Cwm Nanteol a bed of ore is traceable along the sides of the valleys for many miles and has been worked at the Coed and the Lletty Walter mines on the north and at Dolbebin (Dol-y-bebin) mine on the southern bank of the Artro. What is probably the same bed was worked at Cwm-yr-afon farm, two miles farther up the valley, and can be traced south-westwards along the slope above Coed-Crafnant to Ffridd-Dolbebin (Coed-Dolbebin), where two trial holes have proved it. It reappears on the western slopes of Moelfre, where it is worked at the Moelfre mine for a space of about a mile in a southward direction. The bed shewn on the map about $2\frac{1}{2}$ miles to the south is probably a continuation of the Moelfre bed. It crops out on the southern bank of Nant-Egryn, where it is worked at the Egryn mine. It then strikes almost due south through the Hafotty and Cell-fechan mines to the coast near Barmouth.

In the northern part of the district a bed which may be the Lower Manganese Bed has been worked at intervals on the western flank of Moel Ysgyfarnogod. It appears to have been faulted down to Llyn Eiddew-bâch, where ore has been worked, and to Llyn-Eiddew-mawr. A mile to the south-west another outcrop upwards of a mile in length has been worked at the Cwm-mawr mine.

There is some evidence that the Lower Bed crops out in the south-eastern part of the district in Cwm-llechen and Cwm-mynach, near Bontddu and Borthwnog in the Mawddach valley.

The Upper Manganese Bed.

An outcrop about half a mile in length, cut off apparently by faults both eastwards and westwards, occurs a short distance north of Ffridd-llwyn-Gurfal (2 miles east of Harlech). This was referred by Goodchild to the Upper Bed. South of Rhinog Fawr the massive Cambrian grits have been folded into an anticline which pitches south-westward, so that the bed of ore plunges in that direction from near the summit of Rhinog Fâch to the river by Pont Cerig. It has been exploited in a number of shallow workings. This crop is being worked on the mountain a mile south-east of Cwm-yr-afon farm at the Cwm-yr-afon mine. For a distance of three-quarters of a mile along the western side of Foel-wen there are almost continuous old workings on a bed ascribed by Goodchild to the Upper Bed. South of Cwm-Nanteol a short length of outcrop, near Hendre-waelod farm, has been worked on the eastern side of Moelfre at the Hendre mines. North-eastwards of Hendre a bed of ore is worked at Graig-uchaf, where the Rhinog mines commence, which was referred by Goodchild to the Upper Bed.

What appears to be the Upper Bed was worked on the eastern slopes of Diphwys at the old Diphwys mines and is now being

exploited at the new Diphwys mine further south. It then crosses Cwm-llechen and traverses the summit of Mynydd-Cwm-mynach, where there are old levels, and descends into Cwm-mynach, beyond which it rises up to Y-Garn, where also it has been worked. Beyond this point nothing appears to be known of it.

Analyses of Manganese Ore from Merioneth.

	I. Barmouth Black Ore dried at 212° F.	II. Barmouth White Ore dried at 212° F.	III. Diphwys Ore.	IV. Llyn Bod -lyn Ore.	V. Cwm- mynach Ore.
Manganese peroxide	34.48	—	—	—	} 31.096
Manganese protoxide	11.83	29.48	46.50	39.50	
Iron peroxide ...	4.07	2.21	—	—	} 14.450
Iron protoxide ...	—	1.03	4.64	6.48	
Alumina ...	3.06	2.39	7.46	7.82	6.800
Lime ...	2.07	4.53	2.82	3.64	2.286
Magnesia ...	0.31	0.64	0.79	1.35	.244
Siliceous matter ...	38.00	34.95	23.55	27.40	32.600
Sulphur ...	0.08	0.08	trace	—	0.044
Phosphoric acid ...	0.12	0.10	0.24	0.20	0.197
Carbonic acid ...	1.40	23.00	14.14	14.00	1.786
Combined water ...	4.60	1.35	—	—	10.014
	100.02	99.76	100.14	100.39	99.517
The "siliceous matter" contains:—					
Silica ...	22.25	19.40			
Alumina ...	8.25	5.85			
Manganese protoxide ...	5.21	7.44			
Iron peroxide ...	1.45	1.45			
Lime ...	0.62	0.56			
Magnesia ...	0.21	0.21			
Metallic manganese	35.00	28.60	36.01	30.60	27.33
Metallic iron ...	3.96	3.36			10.01
Moisture at 212° F.	7.12	0.26			
Manganese in wet ore	32.51	28.54			
Iron in wet ore ...	2.68	3.35			
Phosphorus ...			0.104	0.087	
Specific gravity ...			3.731	3.658	
Wt. of a cubic foot in lbs. ...			232	228	

I and II Anal. Messrs. Pattinson & Stead, Middlesbrough.
 III and IV „ Dr. Wallace, Glasgow.
 • V „ Messrs. Crawshaw, Cyfarthfa, Merthyr Tydfil.

	Barmouth Black Ore dried at 212° F.	Barmouth Black Ore as received.	Barmouth White Ore dried at 212° F.	Barmouth White Ore as received.	Barmouth White Ore calcined.
Metallic manganese	35.00	32.51	28.60	28.54	35.75
Metallic iron ...	3.96	2.68	3.36	3.35	4.20
Silica ...	22.25	20.66	19.40	19.35	24.25
Lime ...	2.69	2.50	5.09	5.07	6.36
Phosphorus ...	0.05	0.05	0.04	0.04	0.05
Carbonic acid ...			23.00	22.95	—
Combined water ...			20.00	—	—
Moisture ...	—	7.12	—	0.26	—
			99.49		

Anal. Messrs. Pattinson & Stead, Middlesbrough.

Reserves.—The manganese-ore consists of an outer weathered crust of hydrous oxides of manganese and the mass of the bed which is composed of the mixed silicate and carbonate of manganese. Formerly only the weathered or black ore was removed, and along the known outcrops of the beds very little of it remains. The unweathered ore is a flinty-rock banded with various shades of pink, yellow and grey, known as the 'hard rock.' To mine it explosives and heavy hammers have to be used. It seldom exceeds 20 inches in thickness; the country rock is always hard and tough; the beds dip at a high angle, and consequently the removal of the ore by means of 'bed mining' must be attended with heavy labour and a high cost. The reserves, however, are obviously very large, but, as the grade of the ore is low in comparison with that obtained from abroad, the prospects of extensive working are poor.

Mines working the Lower Bed.

CEFN-Y-CLAWDD MINE, TRAWSFYNYDD.

(Active.)

Situated about three miles south-west of Trawsfynydd village.

Geological and Ordnance maps : One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 19 N.E.

This mine is situated low down on the south-eastern slopes of Foel Penolen. It has been recently opened up on an outcrop of what appears to be a portion of the Llyn Dywarchen bed thrown down by a fault that runs in a north-westerly direction immediately to the south of Moel Ysgyfarnogod and Llyn Dywarchen. The mine consists of openworks, connected by track with the road leading to Trawsfynydd.

LLYN DYWARCHEN, LLANDECWYN.

(Active.)

Situated about $2\frac{3}{4}$ miles east-south-east of Talsarnau, on the north-western slope of Moel Ysgyfarnogod.

Geological and Ordnance maps : One-inch New Series Ordnance, 135 ; Old Series Geological, 75 S.E. ; six-inch Ordnance Merioneth, 19 N.E.

The main workings lie southwards of the lake, and run round the crags south-south-east to Llyn Du. The bed is cut off by a fault, coursing north-west and south-east with a downthrow to the north-east, which brings it apparently to the north-eastern margin of Llyn Dywarchen. The main outcrop commences about 270 yards south of the lake at an altitude of about 1,600 feet, and after curving round the end of a ridge runs along it in a south-easterly direction ; as the dip is to the north-west, the outcrop gradually rises towards Llyn Du, where the bed reaches a height of about 1,800 feet.

Through this distance, of about half a mile, the ore, which contains 32 per cent. of manganese, has been extracted by means of openworks. The bed shows a maximum thickness of 18 inches, but is usually little more than a foot.

A track has been constructed alongside the outcrop, but the descent from the workings to Llyn Eiddew-bâch is steep and rocky. From the margin of this lake the ore is carted down Afon Eisingrug to the main road and thence to Talsarnau station, a distance of about 4 miles.

This bed was extensively worked during the war.

LLYN EIDDEW MAWR, TALSARNAU.

(Active.)

Situated $2\frac{1}{4}$ miles south-east of Talsarnau village.

Geological and Ordnance maps : One-inch New Series Ordnance, 135 ; Old Series Geological, 75 S.E. ; six-inch Ordnance Merioneth, 19 S.E.

The manganese-bed which courses south-west from the north-western extremity of Llyn-Eiddew-mawr is about 1 foot thick, and yields 33 per cent. of manganese. There are openworks for a distance of about three furlongs along the outcrop. A cart track leads from the mine to Llyn-Eiddew-bâch, less than half a mile to the north, whence the route followed from Llyn Dywarchen is used.

It is probable that these workings are referred to in the Home Office lists under the name 'Llyn du bach,' from which an output of 2,025 tons is shown in the years 1892 to 1897. This mine was active during the war.

CWM MAWR, LLANDANWG.

(Idle.)

Situated in the upper or northern part of Afon Artro, about $3\frac{1}{4}$ miles east-north-east of Harlech.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 19 S.E.

Openworks on the manganese-bed are more or less continuous for nearly a mile and a half from near Llyn Cwm-bychan northwards. The bed dips up to 40° to the west, but is at times much crumpled. At the northern extremity of the works, three-quarters of a mile north of Cwm-mawr farm, it appears to be cut off by a fault.

At the southern end of the workings there are several old levels. Two of these were in good condition in May 1915, but are only some 20 yards in length. The soft earthy part of the ore, where the carbonate has been largely converted to oxide, has been worked out, with apparently a little of the carbonate. These works are on a steep slope, at the foot of which runs a cart track to Cwm-mawr farm.

By the farm there are some short levels which were worked in 1907-8. Most of them have now been blocked up, but are otherwise in good condition. The bed is here about $1\frac{1}{2}$ feet thick, but is extremely hard.

North of Cwm-mawr the openworks continue for a distance of about three-quarters of a mile. There are occasional levels, now blocked up. The bed of ore averages about 18 inches in thickness, but it is frequently much folded. It dips westwards and locally attains an angle of 40° .

These works were active from 1887 for several years; from 1896 to 1908 a total of 1,656 tons of ore was produced.

From Cwm-mawr farm to Dol-wreiddiog, a distance of nearly a mile, there is a track practicable for wheeled traffic, and from the latter place, a good road down the Artro valley to Llanbedr, about $4\frac{1}{4}$ miles, or to the station 5 miles distant.

At Ffridd Tyddyndu manganese-ore was obtained in the years 1896-1903, and also in 1907 when 175 tons were raised.

LLETTY, COED AND DOL-BEBIN MINES, LLANBEDR.

(Active.)

Situated about $1\frac{1}{2}$ miles east-north-east of Llanbedr village.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 26 N.W.

The bed of ore, which is about 15 inches thick, dips from 10° to 20° eastward. Near the surface the carbonate and silicate of manganese are weathered to pyrolusite. The ore contains 27 per cent. of metallic manganese.

Lletty mine is idle.

Coed mine is worked by inclines and levels driven on the bed.

Dol-bebin mine lies on the southern bank of the Afon Artro. The bed of ore is from 12 to 14 inches thick and is worked by a level, driven along the strike from which the ore is stoped downwards.

The ore is carted to Llanbedr station, a distance of about $1\frac{1}{2}$ miles, and thence to Mostyn.

PENARTH MINE, LLANBEDR.

(Active.)

Situated about $1\frac{1}{2}$ miles north-east of Llanbedr village.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 26 N.W.

The bed crops out along the southern shore of Hafod-y-Llyn, where it is from 12 to 14 inches thick and dips more or less east-south-east at 15° to 20° .

The bed is worked by inclines driven down the dip from which stoping is carried out. The ore contains up to 30 per cent. of manganese, but as the outcrop is only a little above the surface of the lake, heavy pumping is necessary.

MOELFRE AND HENDRE MINES, LLANENDDWYN.

(Active.)

Situated on the slopes of Moelfre, about two miles east-south-east of Llanbedr village.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 26 S.W.

The beds of ore, which are about 12 inches thick, consist of carbonate and silicate of manganese. They are mainly worked by opencast, but a few levels have been driven. The ore yields on assay from 28 to 30 per cent. of metallic manganese.

Moelfre mine is now idle, but since it was opened up in 1905 has produced over 1,000 tons of ore.

Hendre mine is worked chiefly opencast. During the war the beds were followed to a considerable depth. The output from 1892 to 1905 amounted to 1,412 tons of ore.

The ore is carted to Dyffryn station, whence it is sent to Mostyn.

EGRYN MINE, LLANABER.

(Active.)

Situated about three miles north of Barmouth on the western slopes of Mynydd Egryn.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 32 S.W.

The mine is situated on a bed of manganese-ore which continues to the Cell-fechan and Hafotty mines. The outcrop is exposed in old workings extending for nearly four miles in a northerly direction from Barmouth. In 1917 Egryn mine was reopened and was worked extensively during the war. On the dip side of the old workings, shafts have been sunk and some of the opencasts have been reworked. The bed averages about 3 feet in thickness, but locally attains a thickness of 5 feet. The ore contains from 29 to 33½ per cent. manganese, and averages about 31 per cent.

The use of pneumatic drills and of an aerial ropeway that has been erected between the mine and the main road have effected a saving in costs.

From the end of the ropeway the ore is carted to a halt on the railway at Tal-y-bont, between Dyffryn and Barmouth.

CELL-FECHAN, BARMOUTH, AND HAFOTTY, LLANABER.

(Idle.)

Cell-fechan is situated about ¼ mile north of Barmouth, and Hafotty 1¼ miles still farther north.

Geological and Ordnance maps: One-inch New Series Ordnance, 135 and 149; Geological Old Series, 75 S.E.; six-inch Ordnance Merioneth, 36 N.W. and 32 S.W.

The ore consists of carbonate of manganese with black hydrated oxide coating it where exposed to the weather. It occurs in the form of a bed 10 to 12 inches thick, interbedded with Harlech grits and immediately underlain by a seam about two inches thick of hard rock containing numerous cubes of iron pyrites. Large botryoidal lumps of manganese-ore also occur. The whole series dips eastward at about 70°.

Levels have been driven along the bedding-plane; but all of them are flooded and many overgrown. About 1,000 tons of ore were sold between 1899 and 1908. There appear to be reserves of ore at depth.

Mines working the Upper Bed.

CWM-YR-AFON MINE, LLANBEDR.

(Active.)

Situated about 4 miles east-north-east of Llanbedr, and 1 mile west of the summit of Rhinog Fawr.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth 26 N.E.

The bed here is about 12 inches thick, and of good quality yielding about 32 per cent. of manganese.

A well-graded road leads from Llanbedr to Cwm-yr-afon farm, but, between the farm and the mine, transport is difficult. The bed is worked from the surface downwards.

RHINOG MINE, LLANENDDWYN.

(Active.)

Situated on the western slopes of Rhinog Fâch, about 5 miles east of Llanbedr.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 26 S.E.

The bed, which is 12 to 18 inches thick, outcrops at a considerable height on the steep western slopes of Rhinog Fâch. It is mined by extensive open workings. Compressed air plant, erected near the outcrop, operates the pneumatic drills. An aerial ropeway conveys ore down the steepest part of the mountain side to an ore bin, situated on the track, from whence it is transported by motor lorry to the railway. From 1891 to 1894 Rhinog produced 2,659 tons of ore. It has been worked extensively during the war.

DIPHWYS MINE, LLANABER.

(Active.)

This mine is situated about $2\frac{1}{2}$ miles north of Bont-ddu.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 32 N.E.

The bed of ore crops out on the mountain side about 2 miles north of Bont-ddu, trends in a northerly direction towards Llyn Dulyn, and dips at 50° W. It varies from 13 to 15 inches in thickness, and contains from 30 to 34 per cent. of manganese.

The bed is worked from adits driven in below the outcrop, and by levels along the bed.

A track has been constructed recently from the mine to the road within a mile of Bont-ddu, whence the ore is transported by motor lorry to Penmaenpool station.

VOTTY MINE, LLANABER.

(Active.)

Situated on the western slopes of Mynydd Cwm-mynach, about $1\frac{1}{2}$ miles north-north-east from Bont-ddu.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 32 N.E. and 33 N.W.

The bed, which is probably a continuation of that at Diphwys, is 12 to 14 inches thick, and dips at 8° or 10° to the south-east. The ore contains about 30 per cent. of manganese.

The mine has been opened up and is ready for stoping, but only a small quantity of ore has so far been removed. The work has been held up to await the construction of a track across the Cwm-llechen to join the Diphwys track.

CWM-MYNACH MINE, LLANABER.

(Idle.)

Situated on the eastern slopes of Mynydd Cwm-mynach, about two miles north-east from Bont-ddu.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 33 N.W.

This mine, situated on the continuation of the Votty outcrop, on the eastern slopes of Mynydd Cwm-mynach, has not been worked for many years, but from the appearance of the excavations large quantities of ore must have been removed. A disused inclined tramway leads from the mine down to the road in the valley of the Afon Cwm-mynach.

According to the Home Office Statistics, 1,112 tons of ore were raised at this mine between 1889 and 1891; and 501 tons in 1906.

CAE-MAB-SEIFION MINE, LLANELLYD.

(Active.)

Situated about $2\frac{1}{4}$ miles north-east of Bont-ddu, on the eastern slopes of the valley of the Afon Cwm-mynach.

Geological and Ordnance maps: One-inch New Series Ordnance, 135; Old Series Geological, 75 S.E.; six-inch Ordnance Merioneth, 33 N.W.

Cae-mab-seifion mine lies on a continuation of the outcrop which runs through the Votty and the Cwm-mynach mines. The bed is 8 to 10 inches thick and consists of good quality ore.

It has been opened up recently and several hundred tons of ore await transport.

A light railway was in course of construction in May 1921; it will carry the ore from the mine to the main road, whence the ore will be carted to Penmaenpool station.

ARENIG DISTRICT

Manganese-ore has been worked at several localities near the Arenig mountains. The rock in which it occurs is a felspathic ash, generally of a greenish-yellow colour, but frequently stained by iron oxides; to a lesser extent the ore is found in the lavas and intrusive rocks associated with the ash. There are no true veins, but the ore fills joints and irregular fissures, sends out little stringers into the mass of the country-rock, and occasionally swells out to form small pockets.

The prevailing mineral is psilomelane, but pyrolusite has occasionally been found. Apparently neither dialogite nor rhodonite occurs, and it would seem that the oxides have been leached out of the mass of the felspathic rocks and redeposited by surface-waters, not, as in most of the districts described, formed by oxidation of carbonates or silicates. It is frequently accompanied by little veins of quartz.

The nature and occurrence of the ores have been described by Mr. E. Halse, A.R.S.M.,¹ who also gives some particulars of the working. In three analyses made by him the percentage of metallic manganese varied from 43 to 54, the latter being found in the best kidney-ore.

About 1865-70 a considerable amount of work was done in this district. "The ore was dressed and carted 13 or 14 miles to a railway station, and is said to have realised £11 per ton."²

At such prices the ore would certainly pay for working, but "some trials which were recently [about 1890] made in this district have conclusively proved that the ore does not occur in sufficient quantity to be worked profitably at present prices."³

Some saving in the cost of transport may be allowed as a result of the building of the Bala-Ffestiniog railway. The ore would almost certainly die out in depth. It has not been worked much below 10 fathoms.

MYNYDD NODOL, LLANYCIL.

(Idle.)

Geological and Ordnance maps : One-inch New Series Ordnance, 120; Old Series Geological, 74 N.W.; six-inch Merioneth, 13 S.E.

Situated two miles east of Arenig station, on the western slopes of Mynydd Nodol mountain.

There are several old levels, mostly blocked up, but one is accessible for a distance of about 20 yards. There are also small opencuts, which reveal the ash-beds full of irregular stringers of manganese-ore and quartz. The ore is mostly psilomelane, sometimes in the form of kidney-ore.

There is a serviceable cart-road leading to Arenig station, two miles distant.

MOCHOWGRYN, LLANYCIL.

(Idle.)

Geological and Ordnance maps : One-inch New Series Ordnance, 119, 120; Old Series Geological, 75 N.E.; six-inch Ordnance Merioneth, 13 N.W.

Situated on the north side of the Bala-Ffestiniog road and on the east side of Afon Tai-hirion, 2 miles west-north-west of Arenig station.

There are here several more or less definite veins of manganese-ore as well as irregular stringers; the principal vein, about 1 foot wide, runs N. 7° W. and dips east at about 80°.

¹ *Trans. Fed. Inst. Mining Engineers*, vol. iii, 1892, pp. 940-952

² *Op. cit.*, p. 946.

³ *Op. cit.*, p. 941.

The old workings are said by Mr. Halse to be about 30 ft. in depth and the same in length.¹ Small trenches now open show the character of the ore and its mode of occurrence to be the same as at Mynydd Nodol.

There is a good road to Arenig Station.

NANT-UCHAF, ABERGELE RURAL.

(Idle.)

Abergele Hæmatite Company, Limited.

Geological and Ordnance maps: One-inch New Series Ordnance, 107; Old Series Geological, 79 S.W.; six-inch Ordnance Denbighshire, 4 S.E.

'Black oxide of manganese associated with hæmatite was formerly worked at Nant-uchaf, about 2 miles south-west of Abergele, where it occurred in a thick mass in the Carboniferous Basement Beds. The mine is now abandoned.'²

Output in tons.				Output in tons.			
1880	...	...	10	1883	...	...	25
1881	...	...	305	1884	...	...	Nil.
1882	...	...	230				

CARNARVONSHIRE.

DISTRICT V. THE LLEYN PENINSULA.

Most of the manganese-ore that has been raised in Great Britain during the last thirty years has been won from mines in the Llyn Peninsula. The ore appears to be interbedded with rocks of Ordovician age and to consist of large lenticles due to shearing movements.

NANT, BENALLT AND RHIW MINES, RHIW.

(Active.)

Nant mine is situated a quarter of a mile south of Llanfaelrhys church, on the eastern side of a small valley, and not far from Aberdaron.

Benallt and Rhiw mines lie about a mile south-west of Rhiw, and are north and south respectively of the road to Ty Canol.

North Wales Iron and Manganese Company, Limited, 8, Cook Street, Liverpool.

Geological and Ordnance maps: One-inch New Series Ordnance, 133; Old Series Geological, 76; six-inch Carnarvonshire, 44 S.W.

The undecomposed ore contains manganese in the form of carbonate with a small proportion of silicate, but at the outcrop it has been changed into a hydrated black oxide. It occurs as a bed from 10 to 20 feet thick, interstratified with shales and flags

¹ *Op. cit.*, p. 946.

² 'The Geology of Rhyl, Abergele and Colwyn' (*Mem. Geol. Surv.*), 1885, p. 56.

containing *Lingula* and graptolites of Ordovician age. In the shales, which are fragile and papery in the neighbourhood of the manganese-ore, there are nodules of clay-ironstone up to a foot in diameter. The beds have been repeatedly shifted by faults and the ore is often slickensided.

There are extensive intrusions of syenite and greenstone in the shales of both Nant and Rhiw.

At Benallt, where there are several beds of manganese-ore, the shales have been folded into an anticline, and contain many shear lenticles of harder rock (silicified limestone). Occasionally they are brecciated, the fragments being cemented together with massive crystalline natrolite. The limb of the anticline which has been most extensively worked dips south-east at 40° or thereabouts.

It is stated¹ that the average contents of the ore are from 30 to 36 per cent. of manganese, from 7 to 10 per cent. of iron, 18 per cent. of silica, and from .3 to .5 per cent. of phosphorus.

Benallt and Rhiw mines are worked by means of adits and from two shafts 110 feet deep. There are also some open workings on the outcrop.

At Nant the ore yields from 26 to 30 per cent. of manganese. The beds, which dip eastward, are worked by levels driven from an inclined shaft. The ore is taken direct from the mine to a pier for shipment.

The output of these mines has ranged from 4,000 to 7,000 tons of ore a year.

DISTRICT VI. DERBYSHIRE AND WARWICKSHIRE. DERBYSHIRE.

BROWNEGE, WINSTER.

Geological and Ordnance maps : One-inch New Series Ordnance, 111; Old Series Geological, 81 S.E.; six-inch Ordnance Derbyshire, 33 N.E. Latitude 53° 8'. Longitude 1° 39'.

Wad occurs here in flats, pipes and pockets in the Carboniferous Limestone, but so irregularly that it cannot be worked systematically. A shallow shaft has been sunk and the mineral is worked from this as far as practicable.

The wad occurs with ochre and some barytes; it is raised in small quantities and carted to the Via Gellia colour works at Matlock, but its quality is inferior to the foreign material.

It would be possible to raise perhaps 10 tons a week at this place if the demand were to increase.

The mineral is said to occur at other localities in the district.

BONE MILL, GRIFF GRANGE.

Golconda Mining Company.

Geological and Ordnance maps : One-inch New Series Ordnance, 125; six-inch Derbyshire, 34 S.W. Latitude 53° 5' 15". Longitude 1° 37'.

¹ *The Mining Journal*, 1907, p. 828.

Wad and ochre are dug here at the surface, but the material is not of good quality and the demand is small.

WARWICKSHIRE.

Some manganese-ore was raised many years ago at Hartshill Hayes, in Griff Hollow, and at the west end of Wash Lane, near Nuncaton. It occurred in detached pieces ranging from 1 to 60 lbs. in weight, embedded in red clay at a depth of 1 to 8 feet below the surface.¹ Several old pits are marked on the Old Series one-inch Geological Map, Sheet 63 S.W. They are all situated on the outcrop of the Cambrian (Stockingford) Shales.

SCOTLAND.

Ores of manganese have been worked only on a small scale in Scotland and no returns are available as to the output. Manganese minerals are recorded as occurring in many localities by Professor Heddle,² and specimens collected by him are on view in the Royal Scottish Museum, Edinburgh. The finest seem to have come from the following localities: near St. John's Head, Hoy, Orkney Islands (mainly psilomelane); the Laoch Mines near Tomintoul (psilomelane); Laverock Braes, Granham (Grandholm), Aberdeenshire (manganite); Oa Peninsula, Islay (manganite).

In the Geological Survey Memoir on 'The Geology of Caithness,' p. 172, mention is made of a spring in the peat-bogs north-west of Freswick in the Burn of Bog, and about 100 yards from the main stream and 1,660 yards from Freswick Bridge, where oxide of manganese is deposited as a blackish blue mud, with the evolution of sulphuretted hydrogen. An analysis made in the laboratory of the Geological Survey shows that the deposit contains 56 per cent. of oxide of manganese. It is probably of no value as a source of manganese.

In the Geological Survey Memoir on Islay (Explanation to Sheets 19 and 27), p. 76, it is stated that manganese-ore (manganite) occurs in the network of veins traversing the quartzite in the south of the Oa peninsula. At the base of the cliff called Dùn Athad it was worked many years ago, and is said to have fetched £4 per ton. Work seems to have been given up owing to the great difficulty of access.

LEACHT OR LAOCH MINES, TOMINTOUL.

Geological and Ordnance maps: One-inch 75; six-inch Banffshire, 44 N.W. Latitude 57° 13' 40". Longitude 3° 15' 40".

¹ S. Parkes, *Trans. Geol. Soc.*, Ser. 2, vol. i, 1824, p. 168, and 'The Geology of the Warwickshire Coal Field' (*Mem. Geol. Surv.*), 1859, p. 9.

² 'Mineralogy of Scotland,' 1901

Situated at the head of Glen Conglass, $4\frac{1}{2}$ miles S.E. of Tomin-toul.¹ The nearest railway station is Ballindalloch, about 20 miles away from the mines.

The vein has been traced through black slates for nearly 3 miles from Coire Buidhe southwards over the Leachd Hill; it probably occurs on a line of fault, and both walls are much brecciated and very irregular. The ore consists mainly of brown hæmatite, associated with a large quantity of psilomelane and a little wad.

The vein appears to have been opened about the end of the 18th century, and to have been worked for iron-ores which were smelted at Nethy Bridge. 'One hundred tons of ore have yielded as much as 72-75 per cent of iron. The manganese was worked for several years subsequent to 1841 by the Duke of Richmond and a Newcastle firm, who sunk the mine to a depth of 85 feet. The manganese-ore was carried to Speymouth, a distance of 45 miles, and for the first few years brought £8 per ton, but on the price falling to £3 per ton the mining was discontinued.'²

DALROY NEAR CULLODEN MUIR.

Miss Davidson, of Cantray.

Ordnance maps : One-inch 84; six-inch Nairn, 6 S.E.

The trial holes are on the sides of the Dalroy Burn, a tributary of the Nairn river, and about 100 yards downstream from Dalroy, $\frac{3}{4}$ of a mile from Culloden Muir station, and 300 yards from the railway.

The deposit fills a hollow in the 'old schist floor' immediately below the basal conglomerate of the Old Red Sandstone formation. The section exposed in the burn just below the house shews a bed of manganese-ore ranging from a few inches to 6 feet in thickness, and overlain by 20 feet of conglomerate dipping 20° north-westwards. The ore deposit is lenticular or pockety and decreases from 6 feet to a few inches in a distance of about 10 yards.

About 50 yards further eastwards a trial-pit showed the following section :—

Surface deposits	-	-	-	-	-	4 feet.
Conglomerate	-	-	-	-	-	20 „
Dark manganese-ore	-	-	-	-	-	7 „
Breccia with a matrix of black oxide of manganese	-	-	-	-	-	$4\frac{1}{2}$ „
Red hæmatite-ore	-	-	-	-	-	8 „
Schist.						

The hæmatite is 8 ft. thick on one side of the shaft. On the others sides it dies out against the schist.

Analyses of the manganese-ore have yielded from 60 to 70 per cent. of MnO_2 . In the spring of 1922 about half an acre of ore

¹ Special Reports on the Mineral Resources of Great Britain, vol. xi, 'The Iron Ores of Scotland' (*Mem. Geol. Surv.*), 1920, pp. 203-208.

² 'Explanation of Sheet 75' (*M.m. Geol. Surv.*), 1896, p. 34.

had been proved. If the thickness over this area remains constant at 6 feet, the yield should approach 10,000 tons. According to local information fragments of manganese-ore are often found in the fields along the outcrop of the base of the conglomerate. If these statements are true the deposit may be fairly widespread, but there is a strong probability that it is of a pockety nature.

The occurrence of the ore was first observed in 1919 by Mr. Wallace at the exposure in Dalroy Burn. Details taken from a more complete analysis* are as follows :—

MnO ₂	-	-	-	-	-	-	65·87
MnO	-	-	-	-	-	-	7·01
Fe ₂ O ₃	-	-	-	-	-	-	4·11
Al ₂ O ₃	-	-	-	-	-	-	1·95
CaO	-	-	-	-	-	-	·98
MgO	-	-	-	-	-	-	·35
BaO	-	-	-	-	-	-	6·67
P ₂ O ₅	-	-	-	-	-	-	·062
SO ₃	-	-	-	-	-	-	trace
Water, combined	-	-	-	-	-	-	5·05

* Analysis kindly supplied by Mr. Walker, Glenfinlas Road, Edinburgh.

INDEX.

- Abandoned Mines, list of plans of, 10.
 Aberdeenshire, 73.
 Abergelge Hæmatite Company, Ltd., 71.
 Advent Moor, 31.
 Afon Artro, 65, 66.
 Afon Eisingrug, 64.
 Agar section (*see also* East Pool), 18.
 Alloy of tungsten: with iron, 9; with nickel, 9.
 Alloys of tungsten, 8.
 Alluvial deposits, 36.
 ——— overburden, 42.
 Alluvium, 2, 26, 28, 29.
 Altarnun, 2, 26–31.
 Amaloy, 8.
 Analyses of manganese-ore; Arenig district, 70; Benallt Mine, 72; Dalroy Mine, 74; Merioneth, 62, 63.
 Analysis of blue mud, Burn of Bog, 73.
 Andalusite mica-schist, 37.
 ——— slate, 38.
 Andrew, A. R., 60.
 Antimony, 1.
 Antiseptics, 8.
 Apatite, 11, 44.
 Aplite, 26, 29.
 Arenig District, 69–71.
 Arenig Mountains, 69.
 Arsenate of iron, 13.
 Arsenic, 4, 5, 6, 46.
 ——— ore, 4, 14, 16, 27, 31, 33–35, 39, 40.
 Arsenical pyrites, 13, 14, 20, 21, 25, 27, 28, 34, 36, 38–41, 43, 46.
 Arthur, Wheal, 34, 35.
 Ashton, 58.
 Axinite, 53.
- Balleswidden, 10.
 Balmyrheer Mine, 43.
 Barium, 47.
 Barmouth, 61.
 ——— Mine, 67.
 Barncoose Lode, 13, 16.
 Barytes, 44, 72.
 Bayly's Lode, 35.
 Beam, Great, 10, 23.
 Bedford Lode, 38.
 ——— No. 1 Lode, 38.
 ——— United Mines, 10, 35, 37, 38, 39.
 "Bed-mining," 63.
 Bell Metal ore, 14.
- Benallt Mine, 49, 71, 72.
 Bennett's Adit, 40.
 ——— Lode, 41.
 Benny, Wheal, 33, 34.
 Bessemer process, 48.
 Bismuth, 2, 9, 44.
 ——— telluride, 44.
 Blende, 2, 5, 24, 34, 43, 44.
 Bodmin Moor District, 2, 25–31.
 Bone Mill Mine, 72–73.
 Brandy Gill, 44.
 ——— Vein, 44, 45.
 Branwell's Lode, 18.
 Braunite, 47.
 Breage, 1.
 Brentor, 47, 52.
 Brentor District, 55–57.
 Brownedge Mine, 72.
 Brunton Calciner, 4, 32.
 Bugle District, 30.
 Bunny Mine (Old Bunny or Shelton), 24.
 Burn of Bog, 73.
 Busy, Wheal, or Chacewater Mine, 10, 20.
 Buttern Hill Alluvial Works, 29, 30.
 ——— Mine, 29.
- Cae-Mab-Seifion Mine, 69.
 Calcination, 4, 7.
 Caldew, 43, 44.
 Callington United Mines, 10.
 Camborne, 2.
 Cannafra Mine, 27, 28.
 Capel, 12, 14, 21, 38.
 Capel-Engedi, 60.
 Carnarvonshire, 47, 71, 72.
 Carn Brea, 4.
 ——— Mine, 13, 16.
 Carrock Fell, 2.
 ——— Mines, 43–46.
 Cassiterite, 2–3, 5, 7, 11–15, 20–28, 30–34, 38–43, 53.
 Castle-an-Dinas Mine, 2, 6, 7, 22–23.
 Caunter Lode, 17.
 Cefn-y-clawdd Mine, 63.
 Cell-fechan Mine, 49, 61, 67.
 Central Devon United Mine, 40.
 Chacewater Mine (Wheal Busy), 10, 20.
 Chalcopyrite, 2, 15, 22, 27, 39.
 Chalybite, 33.
 Chapple Lode, 13.
 Chillaton Mine, 56.
 China Clay, 23, 28, 31.
 Chlorite, 14, 38.
 Chromium, 8.

- Clay-ironstone nodules, 72.
 Cligga Head Mine, 22.
 Clitters Mine, 10, 35, 39.
 — United Mines, Ltd., 36.
 Cobalt, 8.
 Coed Mine, 61, 65, 66.
 Coed-Crafnant, 61.
 Coed-Dolbebin (Ffridd-Dolbebin),
 61, 65-66.
 Coire Buidhe, 74.
 Colbiggan and Retire Mines, 53, 54.
 Collins, Mr. F. G., 58.
 — Mr. J. H., 25, 30.
 Colouring Materials, 48.
 Combside Vein, 45.
 Copper, 18, 20.
 — Carbonate, 23-26.
 — Lode, 16.
 — metallic, 13, 26.
 — Ore, 11-16, 19, 20, 22, 25,
 26, 33-35, 37-39.
 — oxide, 26.
 — pyrites, 4, 13, 21, 25, 44.
 Cost of working, 6.
 Crofty, South, 2, 3, 4, 5, 6, 13-15.
 Cumberland, 2, 43-46.
 Cwm-Ilechen, 61, 62.
 — mawr, 49, 65.
 — mynach, 61, 62.
 — Mine, 69.
 — Nanteol, 61.
 — yr-afon farm, 61, 68.
 Mine, 61, 67-68.

 Dalroy Mine, 74-75.
 Davy's Shaft, North Gorland Mine,
 21.
 Deal's Kitchen Lode, 38, 39.
 De la Beche, H. T., 11, 52.
 Denbighshire, 59, 71.
 Derbyshire, 72.
 Devon United Mine, 40, 41.
 Dialogite, 47, 48, 59, 70.
 Dimson Mine, 33.
 Diphwys Mine, 61, 62, 68.
 Distribution of Ores: Tungsten ore,
 1-3; Manganese ore, 47-48.
 Dobree's Lode, 16.
 Dolbebin (Dol-y-bebin) Mine, 61,
 65-66.
 Dolcoath Mine, 13, 16, 43.
 Dolomite, 2, 40, 44.
 Dorothy Lode, 28.
 Downgate Consols, 36, 37.
 — Mine, 36.
 Drakewalls Mine, 5, 10, 37.
 Droskyn, and Great St. George, 22.
 Druid Lode, 13.
 Din Athad, 73.
 Dunkin's Lode, 12, 13.

 East Chillaton Mine, 56.
 East Crofty Mine, 15.
 East Hawkmoor, 39.
 East Kit Hill Mine, 32, 33.
 East Pool and Agar Mine, 2-4, 6,
 14, 15-18.
 East Wheal Crofty, 13.
 Edward, Wheal, 34.
 Egryn Mine, 61, 66-67.
 Elvan dykes, 13, 15-17, 21.
 Emerson's Vein, 44.
 Engine Lode, 14, 16, 17.
 Exeter District, 52, 57-59.

 Fanny, Wheal, 43.
 Felspar, 2.
 Felspar Lode, 20.
 Ferberite, 1, 2.
 Ferromanganese, 48, 49.
 Ffridd-Dolbebin (Coed-Dolbebin),
 61, 65-66.
 Ffridd-llwyn-Gurfal, 61.
 — Tyddyndu, 49, 65.
 Fluorspar, 2, 12-14, 16, 19.
 Foel Penolen, 63.
 Foel-Wen, 61.
 Foster, C. Le Neve, 25.
 Franklinites, 47.
 Frementor Mine, 39.
 Friendship, Wheal: Gwennap, 43;
 Martyavy, 10, 40.

 Gabbro, 2, 44-46.
 Galena, 2, 44.
 Gangue, 4, 5, 14, 38-41.
 Garnet, 53.
 Garrow Downs, 31.
 Gaverigan Mine, 54.
 Gazeland Mine, 26.
 Gingerpop Lode, 16.
 Glen Conglass, 74.
 Godolphin Bal Mine, 43.
 Golconda Mining Co., 72.
 Goodchild, J. G., 59-61.
 Goonbarrow Mine, 43.
 Gorland, 10, 21.
 Gossan, 19, 26, 45.
 Gossany quartz, 19, 39.
 Graig-uchaf, 61.
 Grainsgill, 43, 44.
 Granite, 1-3, 11, 12, 14-16, 19-22,
 25-30, 32, 33, 36, 37, 40, 45, 53,
 54.
 Great Beam Mine, 10, 23.
 — Lode, 14, 16-18.
 — St. George and Droskyn
 Mine, 22.
 — Wheal Fortune, 43.
 — Vor, 43.

- Greenstone, 12, 33, 40, 56, 57, 72.
 Greisen, 2, 11, 22, 26, 28, 29, 32, 38-39, 41, 43-45.
 Greisened granite, 23, 37, 39.
 Gunnislake Clitters and Hingston Down, 10, 35, 36.
- Hadfield, Sir R. A., 1.
 Hæmatite, 4, 23, 26, 53-55, 74.
 Hafod-y-llyn, 60, 66.
 Hafotty Mine, 61, 67.
 Halse, Mr. E., 70, 71.
 Halvana (Halvinna) Mine, 10, 26.
 Harding's Vein, 44-46.
 Harlech, 60.
 Harmony and Montague Mine, 43.
 Hartshill Hayes Mine, 73.
 Hawkmoor Mine, 10, 35, 37-38.
 Heddle, Professor, 73.
 Hemerdon Ball Mine, 2, 6, 41-42.
 Hendra Lode, 28.
 Hendre Mine, 49, 61, 66.
 Hendre-waelod farm, 61.
 Herland, Wheal, and Rosewarne, 43.
 Hess, F. L., 1.
 Highburrow Lode, 13.
 Highmoor Mine, 30.
 Hingston and Clitters Mining Co., 36.
 Hingston Down Mine and Gunnislake Clitters, 2, 10, 32, 33, 35, 36.
 Hitchins' Lode, 35.
 Hogstor Mine, 56.
 Holmbush Mine, 10, 33.
 Horseburrow Lode, 28.
 Hübnerite, 1.
 Huxham, 57, 58.
- Illogan District, 30.
 Ilmenite, 30, 42-46.
 Imports of Manganese, 51.
 India, manganese ore of, 48.
 Indian Queen's Mine, 54.
 Iron ore, 13, 14, 34, 47, 53-55.
 — oxide, 5, 6, 47, 69.
 — pyrites, 33, 60, 67.
- Jasper, 57, 59.
 Jewell, Wheal, 40.
 Johnson's Lode, 31, 32.
- Kaolinized granite, 22-24, 41.
 Kelly Bray Mine, 10.
 Keniton Marsh Alluvial Works, 29.
 Killifreth Mine, 20, 21.
 King Brothers, 30.
- Kit Hill, 2-10, 33.
 Kit Hill Great Consols Mine, 32.
 — Mine, 32.
- Land's End District, 11-12.
 Langford, 58.
 Lanhidroek, 54.
 Laoch or Leacht Mines, 73-74.
 Lapworth, C., 60.
 Launceston and Brantor District, 47, 52, 55-57.
 Lava, 40, 52, 55, 69.
 Laverock Braes, 73.
 Leacht or Laoch Mines, 73-74.
 Levant Mine, 12.
 Lewannick (Lawennick), 52.
 — Hill Mine, 55.
 Lidcott Mine, 56.
 Linkinhorne (Linkinghorne), 52.
 Llanbedr District, 59-63.
 Llechwedd-du, 60.
 Lletty Mine, 65-66.
 — Walter Mine, 61.
 Lleyl Peninsula, 47, 71.
 Llyn Cwm-bychan, 65.
 Llyn-du, 64.
 Llyn-du bâch Mine, 49, 64.
 Llyn Dywarchen Mine, 49, 64.
 Llyn Eiddew-bâch, 61, 64.
 — mawr, 61.
 — Mine, 64.
- Long Trench, 42.
- Maclaren, Dr. Malcolm, 16, 17.
 Magenta bronze, 8.
 Main Lode, 13, 17, 25, 35, 37, 38.
 Manganese, Upper and Lower Beds, 60-69.
 Manganese bronze, 48.
 — steel, 48, 49.
 Manganite, 47, 58, 59, 73.
 Maps : *facing* 1, 12, 60 ; *reference*, 10.
 Marmolite, 45.
 Marquis Lode, 37, 39.
 Martha, Wheal, 34.
 Marytavy, 4, 5.
 Maudlin (Magdalen) Mine, 10, 24.
 Mawddach Valley, 61.
 Merioneth, 47, 59-71.
 Mica, white, 11, 29.
 — schist, 2, 44, 45.
 Microcline, 16, 17.
 Middle Lode, 14, 17, 21, 23, 36.
 Mispickel, 2, 11, 12, 14-16, 35, 39, 44, 46.
 Mochowgryn Mine, 70, 71.
 Moelfre Mine, 49, 61, 66.
 Moel Ysgyfarnogod, 61.
 Molybdenite, 2, 21, 22, 44, 45.

- Molybdenum, 37.
 Monkstone Mine, 56.
 Mulberry Mine, 24, 25.
 Mynydd-C'win-mynach, 62-69.
 Mynydd Nodol Mine, 70, 71.

 Nancegollan Mine, 12.
 Nant Mine, 49, 71, 72.
 Nant-Egryn, 61.
 — Uchaf Mine, 71.
 Natrolite, 72.
 Nethy Bridge, 74.
 New Cook's Kitchen Lode, 14.
 — Mine, 13.
 — Engine Lode, 16.
 — Lode, 11.
 — North Lode, 16, 17.
 — South Lode, 17.
 Newton St. Cyres, 58.
 — Mine, 57.
 Nickel, 8.
 Nine Stones Alluvial Works, 29.
 North Devon United Mine, 40.
 — Entral Lode, 16.
 — Gorland Mine, 10, 21.
 — Lode, 14, 16, 21, 23, 36-38.
 — Redmoor Lode, 31.
 — Tincroft Lode, 13, 14, 16.
 — South Lode, 13, 14.

 Oa Peninsula, 73.
 Ochre, 72, 73.
 Old Bunny Mine, 24.
 — Chacewater Mine, 20.
 — Lode, 34.
 — Tincroft Lode, 13.
 Orthoclase, 29.
 Output: of tungsten ores, 7, 8, 9;
 of manganese ores, 49-50.
 — of Mines. *See* under descriptions of individual mines.

 Parkanahy Mine, 10, 18, 19.
 Parkes, S., 73.
 Partinium, 8.
 Peach, 14, 17, 28, 40, 41.
 Pedn-an-Drea Mine, 43.
 Peever and North Downs Mine, 10, 19.
 Pegmatite, 2, 16, 21, 26-29.
 Penarth Mine, 66.
 Pencreba Wood Mine, 57.
 Pengelly Croft Mine, 43.
 Penhale Mine, 2.
 Penhellick, 12.
 Penny or No. 4 Level, 45.
 Plantation Lode, 36.
 Platinum, 8.

 Poldice Mine, 10, 20.
 Poldory Mine, 43.
 Polianite, 47.
 Pont Cerig, 61.
 Pool (*see also* East Pool), 13, 15.
 Prospidnick, Wheal, 43.
 Pryce's Lode, 13, 14.
 Psilomelane, 47, 55, 58, 59, 70, 72, 74.
 Pyrolusite, 47, 48, 55-57, 60, 65, 70.
 Pyromorphite, 2, 44.

 Quartz, 2, 6, 11, 12, 14, 16, 17, 19, 21, 23-25, 27-29, 38, 39, 41, 45, 55, 70.
 Quartzite, 73.

 Red Lode, 14, 16, 18.
 — Moor Mine, 10, 31, 32.
 Redruth District, 2, 12-22, 29.
 Reserves of Manganese ore, 63, 67.
 Restormel Iron Mine, 54, 55.
 Retire (and Colbiggan) Mines, 53, 54.
 Rhinog-Fâch, 61, 68.
 — Fawr, 61.
 — Mine, 61, 68.
 Rhiw Mine, 49, 71, 72.
 Rhodochrosite, 47.
 Rhodonite, 47, 48, 52, 55-57, 59, 70.
 Robinson's Section, South Crofty Mine, 13, 15.
 Roche District, 2, 22-25.
 Roger's Lode, 16, 17.
 Rosewarne, and Wheal Herland, 43.
 Rowden Down, 56.
 Ruthvoes (or Ruthers) and Treliver Mines, 54.

 Saffron bronze, 8.
 St. Austell Granite, 24.
 — Moor District, 2, 53-55.
 St. John's Head, Hoy, 73.
 St. Michael's Mount, 1, 11.
 Scanniclift Cope Mine, 59.
 Schaller, W. T., 1.
 Scheelite, 1, 2, 5, 12, 15, 24, 40-46.
 Scotland, manganese-ores of, 73-75.
 Section at Dalroy Mine, 74, 75.
 Seven Stones Marsh, 32.
 Shelton Mine, 24.
 Silicaspiegel, 48.
 Silver bronze, 48.
 Silver-lead ore, 33.
 Sim's Shaft, 21.
 Skiddaw Granite, 44.
 Smaltite, 21.
 Smith's Vein, 44, 46.

- South Crofty Mine, 2, 3, 4, 5, 6, 13-15.
 ——— Devon United Mine, 40.
 ——— Wheal Crofty, 13.
 Spiegeleisen, 48.
 Spilite, 59.
 Stannine, 14.
 Stannion Marsh Alluvial Works, 31.
 Stellite, 8.
 Stenna Gwynn Mine, 43.
 Streamers Lode, 28.
 Sydenham Mine, 57.

 Tavistock District, 2, 31-42.
 ——— Lode, 37, 39.
 Temple, 31.
 Terrell, Mr. E., 41, 42.
 Tetradyomite, 44.
 Thirwell Section, East Kit Hill Mine, 33.
 Thomas, Captain, 4, 7.
 Tin, 4, 5-7, 9, 21, 24-26, 37, 38, 40, 43.
 — black, 6, 7, 13, 14, 17-20, 28, 29, 31, 33, 35-37, 39.
 — ore, 3, 6, 9, 11, 12, 14-16, 19, 22, 25-27, 29, 31, 33-35, 38-40.
 — oxide, 25, 31.
 — pyrites, 13.
 Tincoft Mine, 4, 6, 7, 10, 12, 13, 15, 16.
 Tinstone, 23, 26.
 Toldish Mine, 54.
 Tolgus Tunnel, 18.
 Topaz, 11, 23.
 Tourmaline, 2, 23, 30, 44.
 Treburland Mine, 10, 27, 55.
 Treliver Mine, 54.
 Trembath Lode, 16.
 Treveddoe Mine (Wheal Whisper), 25, 26.
 Trewint Lode, 28.
 Trewortha Marsh, 31.

 Tungsten bronze, 8.
 ——— steel, 9.
 Tungstic ochre, 24.

 Upton Pyne, 57, 58.
 Uranium Ore, 11, 36.
 Uses: of tungsten, 8; of manganese, 48-49.

 Vein Quartz, 23, 38, 40, 41, 70.
 Vincent, Wheal, 28, 29.
 Vor, Great Wheal, 43.
 Votty Mine, 68, 69.

 Wad, 23, 53-55, 57-59, 72-74.
 Walker, Mr., 75.
 Wallace, Dr., 62, 75.
 Warwickshire, 72, 73.
 West Down End Mine, 55.
 ——— Iron Mine, 53.
 West Wheal Crofty and Longclose Mine, 13.
 Westcott Mine, 56.
 Whimble Lode, 34, 35.
 Whisper, Wheal (Treveddoe Mine), 25, 26.
 Whitstone Mine, 56.
 Wilson, Mr. Anthony, 44.
 ——— Dr. T. Stacey, 60.
 Winster, 48.
 Woodley and West Downs Iron Mines, 53.

 Y-garn, 62.
 Yield of tungsten-ores, estimated prospective, 6.

 Zinc blende, 11, 21.
 Zippeite, 43.

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